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PART II

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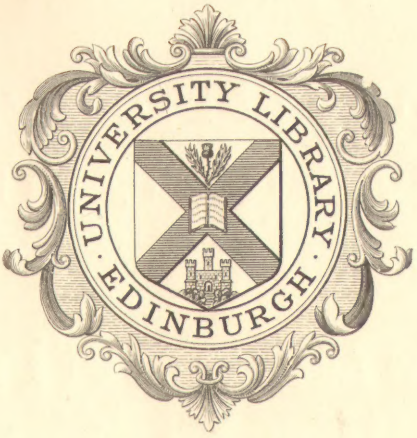

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Summary of Progress

of the

Geological Survey of Great Britain

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PART II

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I.—BOEHMITE AND DIASPORE IN THE BAUXITIC CLAYS OF AYRSHIRE

BY

JACQUES DE LAPPARENT, PROFESSOR OF MINERALOGY AND PETROGRAPHY IN THE UNIVERSITY OF STRASBOURG

Plate I.

IN September 1934 Mr. G. V. Wilson kindly showed me in Edinburgh some specimens of the bauxitic clays of Ayrshire. I had the good fortune to recognize immediately in the microscopic sections *boehmite*, hydroxide of aluminium, which is known to be the essential constituent of a great number of bauxites.[1]

After my return to Strasbourg I studied carefully the specimens which were sent to me from different localities in Ayrshire by Dr. W. J. McCallien of Glasgow and by Mr. G. V. Wilson, and I was able to confirm the presence of boehmite in abundance in the more aluminous specimens of these rocks. In addition to this I found that frequently a small quantity of diaspore accompanied the boehmite. In this contribution I wish to describe exactly how these two hydroxides of aluminium occur in these bauxitic clays and what inferences of a geological character one can draw from their presence.

The specimens which show boehmite in best development are those of the rocks of pisolitic type (Saltcoats, Kilwinning). The more fine-grained and homogeneous rocks which constitute the purer fireclays do not show any boehmite.

The pisolitic specimens of these bauxitic clays are a mass of basaltic fragments around which there are concretionary pisolitic growths. These pisolitic incrustations are of variable thickness and the basaltic fragments vary considerably in size. Some of the pieces of basalt are often much larger than the pisolites and quite free from incrustation. The basalt fragments and the pisolites are pressed so closely together that the cement is reduced sometimes to the vanishing point. It is composed of a very fine argillaceous substance.

Boehmite as very minute crystals, closely associated with kaolinite, forms the principal mass of the rock (kaolinite 51 per cent.; boehmite 40.5 per cent.). It crystallizes principally in the drusy centres of the pisolites or of the isolated basaltic fragments, and the best crystals are to be found in these situations. I have there found the largest crystals of boehmite which I have ever seen. The longest were 0.06 mm. which is no doubt very small, but nevertheless for boehmite quite unusually large. The crystals which I had previously examined were never more than 0.03 mm. in length.

[1] Lapparent, Jacques de, 'La Boehmite et le diaspore dans les fireclays de l'Ayrshire (Écosse)', *Comptes Rendus, Acad. Sci. Paris*, 1934, vol. 199, pp. 1629–1631.

All the optical properties of the mineral have been satisfactorily determined anew on these crystals and I shall give here a short summary of their crystallographic characters.

Orthorhombic prisms carry faces rounding the crystal about the face (100), while the angle is sharp on the face (010), which is not developed. The basal planes (001) are well developed. The crystal projected on the face (001) has a spindle shape. Sometimes there is no rounding of the crystal on (100), and then one can measure an angle which is approximately 120 degrees. The crystals projected on (100) have a rectangular form generally not so high as broad, the height being about half the breadth. Often the angles of the rectangle are truncated by the development of faces which can be interpreted as (011). The angle measured under the microscope between (011) and (001) seems to be about 120 degrees. In consequence, and since the mineral is orthorhombic, it is possible that it possesses a multiple hexagonal lattice with a pseudo-hexagonal axis in the direction of the edge [100]. I have, in fact, been able to separate from the carbonaceous bauxitic clays of Saltcoats some complex groups of boehmites which appear to exhibit a twin law which agrees with a multiple hexagonal lattice, but the specimens are too small to enable me to make a positive assertion on this point.

The boehmite has a perfect and easy cleavage in the direction of (010). This cleavage was evident in the microscopic sections when the larger crystals had been crushed during the preparation of the slides.

The optical properties of the boehmite are also very characteristic. The plane of the optic axes is parallel to (001) and the vibration direction with the lowest refractive index is perpendicular to (001), so that the optical elongation of the crystals is positive. This property enables us to distinguish easily between boehmite and diaspore, for the optical elongation of the crystals of the latter mineral is negative when observed on whole crystals; it is sometimes positive, sometimes negative, when observed on sections of crystals, but in the case of the bauxitic clays there are always whole crystals on which one can make observations. The birefringence measured on the boehmites of Ayrshire is 0.013. The mean refringence of these boehmites measured by means of liquids of known refractive index appears to be close to 1.645 (diaspore has a mean refractive index of 1.72 which is very easily distinguished from that of boehmite).

Boehmite is intimately connected with kaolinite which as a fine-grained matrix encloses the masses of crystals. When it is abundant the kaolinite is seen to fill the drusy cavities on the edges of which the large crystals of boehmite have formed. This proves that the crystallization of boehmite has preceded that of kaolinite. This is a relation which I have always been able to establish in my studies of bauxites. It would be erroneous to suppose that the

hydroxides of aluminium arise from the alteration of kaolinite as has sometimes been suggested.

The diaspore appears here and there in the slides of bauxitic clays as crystals 0.03 mm. in length which occur always in the middle of the most fine-grained parts of the rock, and in the groups of boehmite as very minute crystals which often cannot be resolved by the microscope.

I shall say at a later stage what geological inferences can be drawn from this observation.

The form of the crystals of diaspore is always that which corresponds to the tabular shape of the crystals on (100) but with marked elongation in the direction of the axis [001]. It is the usual form which always appears in the bauxites with diaspore (bauxites crétacées du *Pays de Fenoullet,* dans les Pyrénées Orientales, en France).[1]

The fragments of basalt in the bauxitic clays vary much in structure; some are typically doleritic but others appear to have been originally glassy. They are all converted into a mixture of boehmite and kaolin, more or less rich in diaspore. Their iron-oxide minerals are sometimes ilmenite but there was also some original magnetite which has now been converted into goethite. In the last stage of decomposition the titaniferous iron-oxide has yielded anatase, which may be said to be the characteristic form which titanium oxide possesses in the bauxitic clays. However, in certain pisolitic crusts there are small crystals of rutile. Rutile is known to be a frequent product of the decomposition of micas such as biotite in the zone of cementation in the earth's crust. It is always found as an accessory element of sedimentary clays. Therefore we may feel assured that it appears in the pisolitic clays as a derivative from an original clay material rather than from a basalt. Accordingly the bauxitic clays, though principally due to the weathering of basalt, contain also in some measure products derived from rocks of other types. The investigations of Wilson have conclusively shown that there were, above the masses of basalt which were spread out at the junction of the Millstone Grit and the Coal Measures, a whole interbanded series of bauxitic clays and of sandy and carbonaceous sediments up to the horizon of the Raise Coal.

The investigation of the carbonaceous sediments associated with the bauxitic clays of Ayrshire leads to a comparison of those rocks with the typical bauxites rich in boehmite of the South of France (Department of Ariege, Pyrenees). Certain deposits of bauxite of this region on account of their richness in silica might be considered as bauxitic clays rather than true bauxites, and it is interesting to note that the abundance of boehmite as clearly visible crystals seems to be connected with the presence of considerable

[1] Lapparent, Jacques de, 'Les bauxites de la France méridionale,' *Mém. Carte. Géol. France,* 1930.

deposits of lignite resting on the bauxites. Those bauxites are Cretaceous. Owing to the denudation which preceded (or was contemporaneous with) their deposition, they rest on the limestone and dolomites of the Upper Jurassic, but the superincumbent deposits are essentially rich in lignite and these immediately precede the deposit of the Aptian limestones.

The same features are repeated among the bauxites of Provence which also are Cretaceous though belonging to a somewhat more recent stage. The clays and siliceous clays which cover the deposits of bauxite in Provence and which contain well-developed boehmite are covered in turn by deposits rich in lignite.

For these reasons we have long been of opinion that the humic components of the water draining from these peaty forests in these different periods had in some measure favoured the production and the crystallization of boehmite, and it seems reasonable to extend the same conclusion to the bauxitic clays of Ayrshire.

It is of no importance that the clays of Ayrshire were derived from a basalt while in France the bauxites were formed from the residual clays of weathered argillaceous limestones. In both cases we are concerned with the operation of the hydrolyzing action of tropical climates upon silicate minerals. The bases were removed and a mixture of silica and alumina remained along with water in the state of a colloidal gel. The different hydroxides of aluminium have slowly developed as this gel passed into the crystallized stage owing to the conditions to which it was subjected.

We have shown in a recent account of the Cretaceous bauxites of Greece[1] that diaspore, which is an essential element of these rocks, owes its origin to the subsidence of an area of the earth's crust where the development of bauxite was going on. The diaspore was produced through the rise of the isogeotherms to a level somewhat higher than those which correspond to the development of boehmite. I think that the same conclusions apply very well to the problem of the Ayrshire bauxitic clays.

We may suppose, therefore, the weathering under the influence of a somewhat tropical climate of an area of basaltic rocks poured out soon after the beginning of Millstone Grit times, and that the original minerals were in this manner hydrolyzed. As the basalt breaks up into fragments it forms impure alumino-siliceous gels which retain to some degree the primary structure of the basalt. These fragments are collected in basins which are flooded by humic waters, and under these conditions the mixed alumino-siliceous gels are formed in which boehmite and kaolinite come to be developed. The waters which drain into these sinking basins carry other materials than basalt, such as superficial clays of which the original presence is betrayed by the rutile which occurs in the

[1] Lapparent, Jacques de, *Comptes Rendus sommaires de la Société Géol. de France*, 1934, p. 192.

pisolitic crusts. As subsidence goes on and the gel becomes older those parts which have not been saturated with humic solutions are not completely transformed and are in turn affected by the rise of the isogeotherms. In those parts of the gel that are not completely transformed the germs of diaspore will form, and these will go on developing even at the expense of the minute crystals of boehmite in a manner similar to the development of crystals in general from the micellae of a colloidal mass. The colloidal condition in turn will disappear when the kaolinite crystallizes and the development of diaspore will stop.

The occurrence of diaspore and boehmite is comparable to the 'index minerals' which have been described by English petrographers (Barrow and Tilley) in their studies of metamorphism. In accordance with this hypothesis we understand why the diaspore crystals are always found among the sub-microscopic crystals of boehmite. In such situations the colloidal gel has not been able to promote the development of boehmite since it was protected from humic solutions.

It is necessary to remember that there has not been a transformation of boehmite to diaspore. These two minerals differ widely from one another and in conclusion I wish to show what are the chemical relations between them.

There are three hydroxides of aluminium and all of them may be found in bauxitic deposits. They are gibbsite, boehmite and diaspore; the first is often called tri-hydrate of alumina, the second and third being mono-hydrates. The formula of the first may be taken as $Al(OH)_3$ and by so doing we indicate clearly its structure in which the ions (OH) are grouped in an octahedral manner around the ion Al, as it can be in a compact hexagonal assemblage of (OH). By analogy with the structure of lepidocrocite, which is a homologue of boehmite in the ferric series, and which Goldzstaub has recently shown to have the type of structure similar to FeOCl, it is possible that boehmite may have a formula AlO(OH) corresponding exactly to the structure in which the three ions Al, O and (OH) are intimately associated and have their centres in one plane. They form by their repetition in a perpendicular direction sheets parallel to the cleavage.

But the structure of diaspore is quite different. It belongs to the same type as olivine or chrysoberyl where we have an association of complex ions SiO_4 in one case and BeO_4 in the other with Mg_2 for olivine and with Al_2 for chrysoberyl. The complex ions form a close hexagonal assemblage in which the ions RO_4 have a tetrahedral form and make tetrahedra which are independent of one another. We consider that in diaspore the ion RO_4 is an ion H_2O_4 of such a kind that there is no room to regard the ions as (OH) but that the hydrogens and oxygens

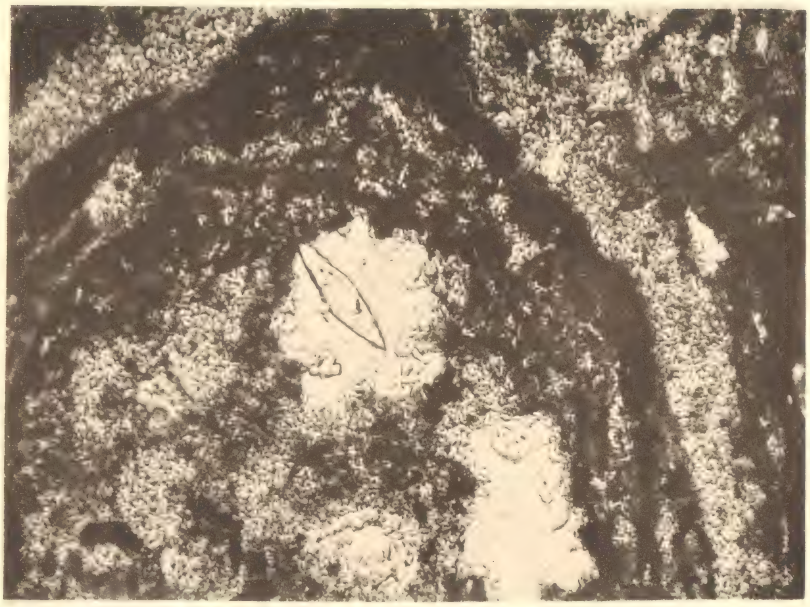
form a complex tetrahedral ion. Thus diaspore, though having the same formula as boehmite, would be different both chemically and physically.

The series of hydroxides of aluminium which form the bauxitic rock would then comprise three types of structure chemically different. Firstly the type where there are only the ions (OH), gibbsite; secondly the type having the ions O and the ions (OH), boehmite; thirdly the type where there are neither the ions O nor ions (OH) but a complex ion H_2O_4. On this supposition the physical conditions in which these substances are formed would have been quite different.

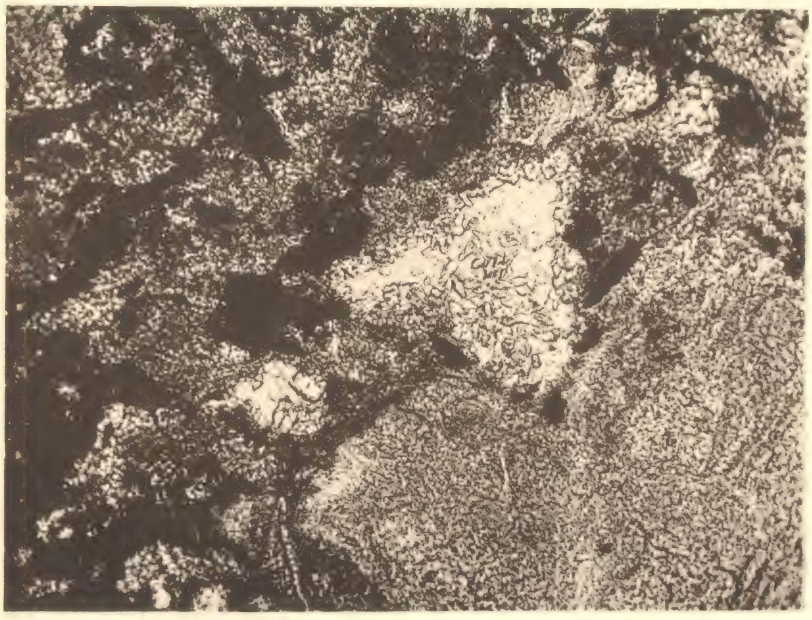
It is interesting to perceive that the bauxites which contain gibbsite have never been under conditions of subsidence during the time when the original gel was being formed from which the gibbsite was derived. The bauxites which were originally not covered up by sediments, but which actually were exposed at the surface during a period when the country was being elevated, are the bauxites that contain gibbsite.

Summary.—The bauxitic clays of Ayrshire contain boehmite and diaspore, minerals characteristic of bauxites, and consequently have been correctly described by Mr. G. V. Wilson as bauxitic clays. The conditions under which these rocks were produced prove that they began as an alumina-silica gel resulting from the hydrolysis of silicates under conditions of tropical climate. The evolution of this gel went on during regional subsidence, at first in presence of humic waters which favoured the crystallization of boehmite and subsequently at such a depth that the diaspore could crystallize owing to a rise of the isogeotherms. The formation of kaolinite was subsequent to that of the hydroxides of aluminium.

I wish to express my indebtedness to Dr. McCallien and Mr. Wilson for their kindness in supplying me with materials for description.



(1) BOEHMITE CRYSTAL IN A DRUSY CAVITY IN PISOLITIC CLAY.



(2) GROUPS OF BOEHMITE CRYSTALS IN DECOMPOSED BASALT, AYRSHIRE BAUXITIC CLAY.

Description of Plate I

1. The largest known crystal of boehmite formed in a drusy cavity of pisolite. Other small crystals isolated or grouped together are visible. All the crystals are enclosed in kaolinite. The part of the rock surrounding the visible crystals is formed of a mass of very small boehmites and is stained by iron oxide. Locality: Saltcoats Beach. Magnification 315 diameters.
2. Group of crystals of boehmite in a drusy cavity in a fragment of basalt. Locality: Dubbs Quarry, Kilwinning, Ayrshire. Magnification 170 diameters.

II.—PLEISTOCENE DREIKANTER IN THE VALE OF YORK

BY

WILFRID EDWARDS, M.A.

Plate II. : Text-figures 1-3.

INTRODUCTION

THE widespread presence of dreikanter[1] in the Vale of York has become apparent during the resurvey of the northern part of the Yorkshire Coalfield and contiguous areas to the east. The district investigated (Fig. 1) lies mainly within the lower part of the Aire basin and thus comprises part of the western flanks of the Vale of York south of the Escrick moraine. The country is littered with patches of ' older drift ' (see p. 16) and with the waste from the interglacial denudation of this drift, and it is the harder stones derived from these deposits which show evidence of wind erosion.

Following the discovery in Whitley Sand Pit, near Selby, of an old land-surface studded with dreikanter and overlain by the later Vale of York drifts, similar sand-blasted stones were found on the surface of a wide area between Selby and Wakefield. As at Whitley the dreikanter are pebbles, cobbles and boulders composed mainly of hard Carboniferous sandstone and ganister; sand-blasted stones (eoliths[2]) of the same rocks and of chert are also common. These materials, with the occasional quartz pebbles which are similarly wind-worn are the hardest substances in the older drifts; post-glacial weathering has not visibly modified their surfaces, but the heavier cobbles and boulders have been scratched by the plough. Where stones composed of the local Coal Measures and Magnesian Limestone rocks lie scattered on the surface they are never, as far as observation has shown, found sand-blasted, and it may be supposed that dreikanter made of such comparatively soft rocks have been destroyed by subsequent weathering.

While in very exceptional circumstances water-borne sand may produce comparable results, it is considered that all the stones here described, including those found beneath water-deposited sands, have received their present shapes under conditions of subaerial erosion.

DESCRIPTION OF THE DREIKANTER

Specimens ranging in size from 2-inch pebbles to a boulder nearly 14 inches across are shown in Plate II. Faceted boulders of much larger size were seen at Whitley. So similar are the

[1] The term is used in the broad sense to denote wind-faceted stones, irrespective of the number of facets.

[2] See Raw, F., ' Triassic and Pleistocene Surfaces on some Leicestershire Igneous Rocks,' *Geol. Mag.*, vol. lxxi, January 1934, p. 29.

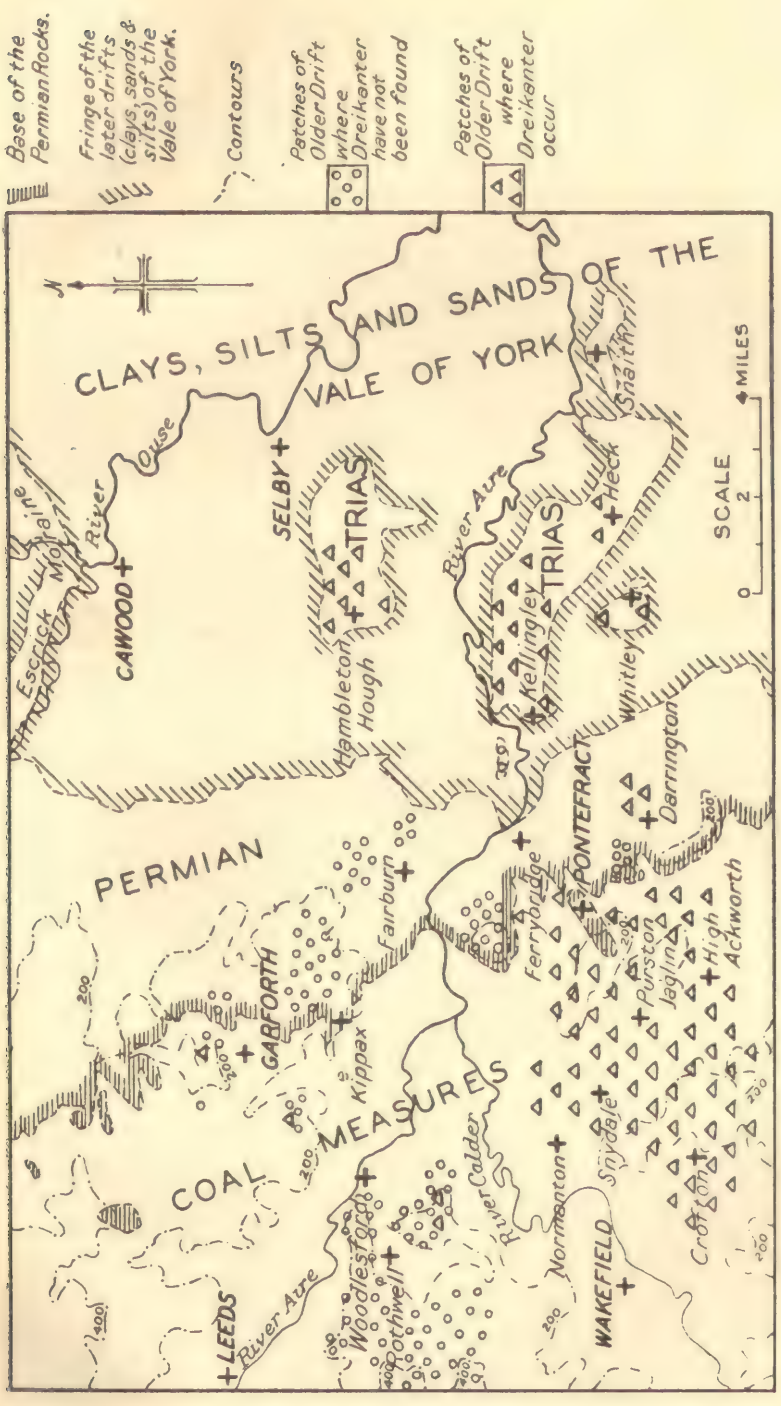


FIG. 1—*Sketch Map showing the Distribution of Dreikanter between Selby and Wakefield.*

present specimens to those of the same lithological types found elsewhere, and already described in detail by a number of authors,[1] that a brief description is sufficient, and even so involves some repetition of parts of these accounts.

It would appear that wind-driven sand imposes on each of the common rock-types a characteristic pattern. The best examples of wind-faceted stones are composed of homogeneous sandstones and grits of Upper Carboniferous age. One to five or more facets, meeting in sharp, gently-curved or nearly straight edges, are found on the upper surface. Sometimes the facets surround an area at the top where the original surface of the stone is but little modified; often this area has disappeared and the facets meet near the top of the stone. Among these examples the typical 'Dreikanter', with three facets, is very common. Pebbles are frequently found with two facets meeting in a sharp ridge along the top to produce a shape like that of a brazil-nut.

It is assumed that the facets described above are produced solely by sand-blast. Many stones show less regular shapes due to fracturing, the exposed surfaces having been subsequently wind-polished. With fissile sandstones perfectly flat surfaces are common, produced by splitting along bedding planes (see Plate II, Fig. 4); in many cases fractured surfaces appear to bear no relation to planes of weakness in the rock.

The small quartz pebbles and (at Whitley) the quartzite pebbles derived from the Trias are sometimes found beautifully wind-faceted. Ganister and ganister-like sandstones show irregular facets which were probably determined by fracturing. They also show the 'dimpled' surfaces mentioned below.

Many stones are faceted on both top and bottom, having apparently rolled over. These are the 'Doppel-Dreikanter' of German authors. The bulk of the large specimens found were only faceted on their top sides.

Chert, the hardest substance found in the older drifts, has merely suffered surface-polish, although fracture-faces sometimes give a rough imitation of faceting.

The nature of the sand-blasted surface varies according to the material, but in all cases roughness is eliminated by the development of a polish which has missed no part of the exposed surface. Even in coarse Millstone Grit the polish extends into the depressions and cavities between the protruding quartz grains, while these grains show a glossy finish, sometimes with miniature facets. Bedding-planes of sandstones are commonly defined by lines of minute cavities, occasionally by superficial fluting which may develop into sharp-edged grooves in the case of strongly laminated

[1] See especially Bather, F.A., 'Wind-worn Pebbles in the British Isles,' *Proc. Geol. Assoc.*, vol. xvi, 1899-1900, pp. 396-420, with a valuable bibliography of work by foreign authors; Wills, L. J., 'On the occurrence of Wind-worn Pebbles in High-level Gravels in Worcestershire,' *Geol. Mag.*, July 1910, pp. 299-302; Jackson, J. W., 'The Association of Faceted Pebbles with Glacial Deposits,' *Mem. & Proc. Manch. Lit. & Phil. Soc.*, vol. lxii, Part III, Session 1917-18, p. 13; Swinnerton, H. H., 'Periods of Dreikanter Formation in South Notts.,' *Geol. Mag.*, May 1914, pp. 208-211.

specimens. Ganister presents a 'waxy' polish, and is commonly covered with shallow irregular depressions, aptly described by Professor Wills as 'dimples' (*op. cit.*, p. 299). Very characteristic are the holes representing rootlets; these, when normal to the surface, are funnel-shaped at the top, like countersunk screw-holes (see Plate II, Fig. 9).

With very few exceptions the polish extends over the unfaceted bases of the stones, while many stones without facets are found to be similarly polished. A ready explanation is afforded by the fact that dreikanter in desert areas are frequently shifted and even overturned when the wind undercuts the sand on which they rest.[1] Dr. Jackson contends that facets are initiated mainly by fracturing under temperature-variation and frost-action, those imposed by sand-blast alone being exceptional (*op. cit.*, *p.* 23). An examination of many Yorkshire specimens leads to the conclusion that fracturing has been very common, particularly so with chert, ganister and fissile sandstones which split readily along the bedding, but also with the more compact sandstones. Stones are common, however, in which the original rounded surface shows the presence of incipient facets meeting at the top (Plate II, Fig. 1); these form one end of a graded series which includes the more shapely and symmetrical stones, and especially the typical three-faceted 'dreikanter'. Wade (*op. cit.*, p. 394, Plate xxxi) shows a similar graded series from Egypt. It seems reasonable to suppose that while polishing was rapidly effected by wind-driven sand, faceting of unfractured rocks required a much longer time and was only imposed on those which remained unshifted for considerable periods.[2] Alternatively, the abrasion due to constant settling down in shifting sand might suffice to polish the base of a dreikanter which never got overturned.

It must be mentioned that in the majority of the dreikanter found in the Vale of York the facets bear no relation to planes of bedding and jointing. If fracturing has produced these facets its cause must be sought in some specialized form of flaking at present undescribed, which has acted independently of the structural planes of weakness in the rock. Further experimental work in the production of dreikanter is highly desirable.[3]

The Possible Direction of Wind as Indicated by Facets

Only in Whitley Sand Pit could a number of specimens be examined *in situ*, and no evidence of former wind-direction was found. This accords with the results obtained in Egypt by Walther,[4] who stressed the eddying of the wind around the larger

[1] Bather, F. A., *op. cit.*, pp. 405, 406; Wade, A., 'On the Formation of Dreikante in Desert Regions,' *Geol. Mag.*, Sept. 1910, pp. 394-398.

[2] See Bather, F. A., *op. cit.*, p. 405.

[3] Bather, F. A., *op. cit.*, p. 407.

[4] Walther, J., 'Die Entstehung von Kantengeröllen in der Galalawüste' *Sitz.-ber math. -phys. Classe k. sächsischen Ges. Wiss.*, xxxix, 1887, pp. 133-136, 'Die Denudation in der Wüste und ihre Geologische Bedeutung u.s.w.,' *Abhandl. k. sächsischen Ges. d. Wiss.*, xxvii, 1891, pp. 345-570. See also Bather, F. A., *op. cit.*, p. 406.

stones and the continual shifting of individuals. Stone obtained similar results in India.[1] Dr. Raw, by examining large sand-blasted rock-surfaces in Leicestershire, has demonstrated a former prevalence of south-east winds,[2] while Bather gives cases in which the direction of wind could be determined.[3]

Details of Occurrences

A. *Whitley Sand Pit, about 4 miles south-west of Selby.*—At the west end of this pit the junction between the Trias sands and the later Vale of York drifts is a horizontal surface littered with wind-faceted stones (see Fig. 2). Stones of all sizes from pebbles to considerable boulders are found, the cobble grade being commonest. Compact sandstones predominate and ganister is abundant, while coarse pebbly grit occurs. All these are Carboniferous rocks, but small faceted pebbles of grey quartzite derived from the Trias are also found. Every stone found on this surface was sand-blasted and nearly all bore facets, most of the larger boulders on their upper surfaces only.

With trifling exceptions all these stones were derived, not from the Trias, which contains only small quartzite pebbles, but from two gravel outliers which cap low hills half a mile to the south; they represent the waste from subaerial denudation of these gravels, distributed over the gentle slopes around the outliers either by hill creep or by solifluxion (see Fig. 3). In lithology and grade they match exactly the elements of those coarse gravels, which are part of the early glacial accumulations of the Snaith-Kellingley Ridge.[4] The formation of the dreikanter post-dates the formation—and some drastic denudation—of these gravels.

The sand at the dreikanter-bearing surface compares closely with the Bunter sands just below but is of finer grade and contains much silty dust. It differs also from the Bunter in that a few of the grains are rounded; but the bulk are not. In view of the evidence mentioned above for the blowing away of sand this is not unexpected.

The freshness and lack of disturbance of the dreikanter suggest the gentle encroachment of rising waters over the wind-swept surface, with immediate deposition of the overlying sediments. These sediments are evenly-bedded sands with streaks of coaly dirt, ripple-bedded in places, and typical of the later Vale of York drifts. They lie some 15 to 20 feet above the general level of the top of these drifts, and may thus be of earlier age. Alternatively their higher position may be regarded as due to marginal deposition of the later drifts, which by their character were deposited in quiet water probably of some depth.

B. *Sundry other occurrences.*—So far as it has been ascertained

[1] Stone, G. H., 'On the scratched and faceted stones of the Salt Range, India,' *Geol. Mag.*, dec. iii, vol. iv, 1889, pp. 415-425.
[2] Raw, F., *ibid.*, pp. 23-31.
[3] Bather, F. A., *op. cit.*, pp. 402, 403.
[4] Kendall, P. F. and H. E. Wroot, 'Geology of Yorkshire,' p. 48. See also below, p.16.

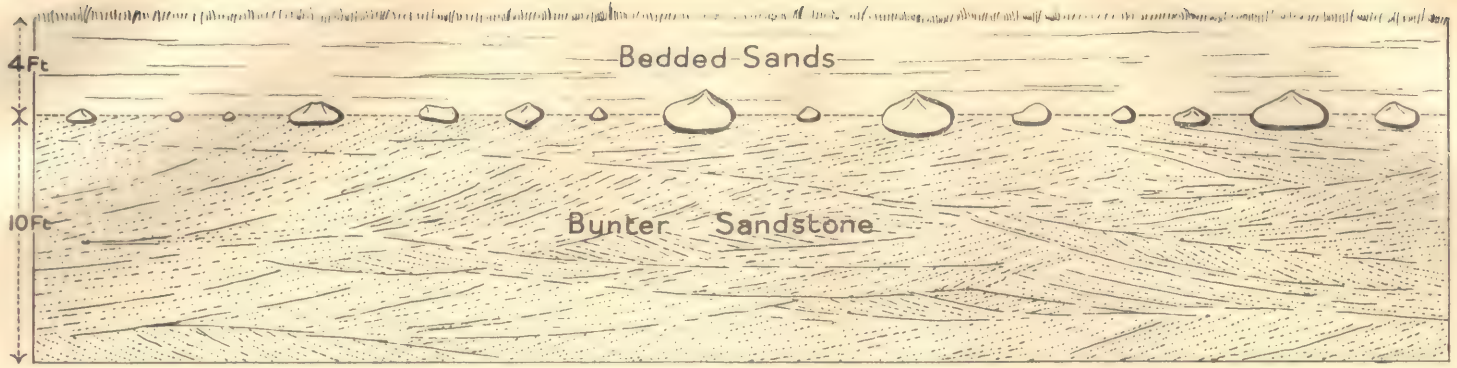


FIG. 2—*Section at west end of Whitley Sand Pit.*
Dreikanter on a land-surface buried by sands probably of late Pleistocene Age.

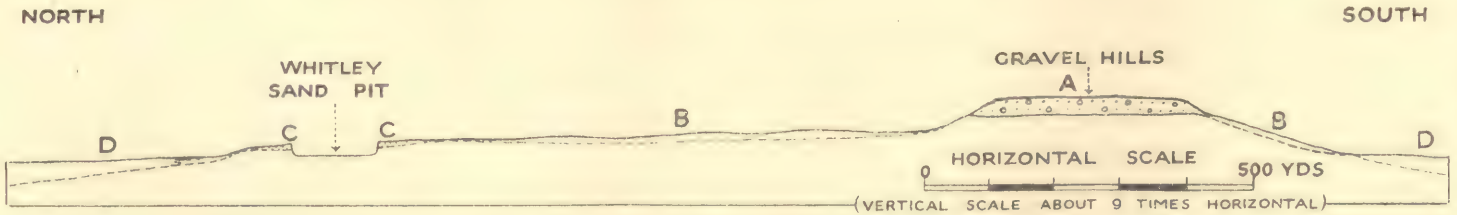


FIG. 3—*Generalized Section across the outcrop of Trias at Whitley.*

A—Old Glacial Gravels.
B—Bunter Sandstone with a thin coating of unbedded stony loam.
C—Bedded sands overlying the Dreikanter-surface.
D—Later drifts of the Vale of York.

the distribution is shown in Fig. 1. While sand-blasting has affected the older drifts which lie on the solid rocks no evidence of the sort is found on the newer drifts of the Vale. Certainly these fine-grained sediments support only an extremely light scattering of pebbles, but in any case they are younger than the dreikanter-bed at Whitley. Further, the gravelly parts of the first terrace above the flood-plain of the Aire and Calder, which is contemporaneous with much of these later drifts, have not provided any dreikanter. Nor has the still older second terrace, although much of its area has been carefully searched.

On the Triassic ' islands ' which rise out of the newer drifts at Hambleton, Brayton Barff, Kellington and Whitley and are mantled by the old glacial gravels and their waste, there is abundant evidence of wind-erosion, apparently of the same age as at Whitley. On the Permian outcrop, sand-blasted stones have been found only near Darrington.

The abundance of wind-faceted stones on the wide area of Coal Measures between Pontefract and Wakefield is remarkable. Cobbles and boulders of sandstone and grit, fragments of chert and occasional quartz pebbles can be found in almost every field, practically without exception sand-blasted, the sandstones and some of the quartz-pebbles being strongly faceted as by prolonged wind-action. Excellent specimens derived from a clayey superficial layer, probably a solifluxion-product, lie about the floor of the brick-pit at Ackton Hall Collieries. They were found in similar circumstances at the old pit (now being filled in) at Sharlston West Collieries, and in Healdfield Brick Works, Castleford. At the latter locality one specimen was found in the base of bedded sands of Second Terrace age.

These faceted stones are scattered indiscriminately over both sandy and clayey land, and occur in profusion in the thick beds of unsorted clay and loam which occupy the upper courses of the shallow valleys of these areas, notably near East Hardwick, Purston Jaglin, Snydale and Normanton. These deposits can only be satisfactorily accounted for by assuming extensive solifluxion under cold wet conditions soon after the wind-erosion period. They appear, in fact, to be the equivalent of Coombe Rock. It is indeed probable that most of the wind-worn stones found at the surface in this area have been redistributed by solifluxion (see also p. 17).

This area of abundant dreikanter is divided by the rivers Aire and Calder from a tract to the north where evidence of wind-erosion is almost lacking, despite the local abundance of older drift patches with the same rock types. Sand-blasted rocks have only been found on the plateaux around Rothwell, on the high ground between Swillington and Garforth Bridge, and on an area near Stank House, Garforth. Further, the rocks are seldom found faceted, only polished. Polished fragments of reddish ironstone found near Stank House are preserved in Leeds University Geological Department, and were shown to the author by Dr. H.

C. Versey. They are a rock type which has not elsewhere been found sand-blasted.

Apparent Limits of the Dreikanter Area

Since observation has been concentrated mainly within the area shown in Fig. 1, further search may be expected to prove the occurrence of dreikanter over a far wider district. Their distribution is, however, inexplicably patchy. There are wide areas south of the present one where, for no reason yet obvious, they are not found. The same is true of the Magnesian Limestone outcrop and of the Coal Measures north of the Aire and Calder, where sand-blasting of a feeble nature only is indicated at the three localities noted above. Various theories might be propounded to explain these lacunae, such as lingering of snow-sheets, unequal rate of establishment of vegetation, barriers, such as the Aire and Calder, to sand-drift, but lack of evidence and the necessity for unwarranted assumptions as to climatic conditions must leave the discussion of such theories unprofitable. It must not be forgotten, however, that wind-faceting can be a rapid process.[1]

Farther north the York and Escrick moraines were searched fruitlessly for sand-blasted stones by Dr. Raw,[2] and further search over part of the same area has given a like result. Professor Kendall, however, records sand-blasted stones at High Catton, within the Escrick moraine,[3] and Mr. J. V. Stephens has found one specimen, of chert, at Poppleton, York, behind the York moraine.

Other Records from Yorkshire

Owing to the kindness of Professor Fearnsides and Mr. Wilcockson, several occurrences noted by them in more southern parts of Yorkshire may be mentioned here.

Glazed grit pebbles occur in the solifluxion drift along the Don valley, and some with dreikanter-shapes have been found in shallow excavations between Templeborough and Rothervale. Sand-blasted and faceted stones are found on the surface of glacial gravels around Bawtry and Finningley, and are probably contemporaneous with those between Selby and Whitley.

East of Bawtry sand-blasted stones are abundant in the gravels of Austerfield and Misson; at a pit one and a half miles east of Finningley great numbers of faceted boulders are dredged up from the lower part of a gravel bed. This evidence suggests an earlier period of Pleistocene wind-erosion; so also does a former section

[1] Bather, F. A., *op. cit.*, p. 407.
[2] Raw, F., *op. cit.*, p. 29.
[3] Kendall, P. F. and H. E. Wroot, *op. cit.*, p. 527.

at Heck, where Professor Fearnsides found dreikanter in false-bedded sands associated with the old glacial gravels; the sands here, however, may have been contemporaneous with those at Whitley.

Dr. Wray and T. Eastwood have found wind-faceted stones on glacial gravels at Wykeham, between Pickering and Scarborough, but this is the only record the author knows from East Yorkshire, excepting the fluted chalk surface described in the buried cliff at Sewerby.[1]

The possible position in the local Pleistocene succession, and a comparison with other Pleistocene occurrences

With the possible exception of those in the Heck gravels the faceted stones of the Selby-Wakefield area are considered to have been made during one period; the assumption harmonises with the evidence available, but may yet prove to be unjustified. Unfortunately there is little prospect at the moment of fixing the precise age of this period. In the first place the Whitley section is capable of two interpretations; secondly the Pleistocene deposits in the Vale of York have not yet been worked out in detail and cannot be correlated with the deposits of other areas.

The idea that the Vale of York suffered an early and extensive glaciation which laid down the older drifts, followed first by a prolonged denudation period and then by the deposition of the newer drifts, has long held sway, and was enunciated most clearly perhaps by Messrs. Kendall and Wroot.[2] The work of the Geological Survey now in progress on the western side of the Vale confirms this, but at the same time it has become apparent that the glacial geology of the Vale is of extreme complexity. Avoiding details as much as possible it may be stated that the older drifts, corresponding more or less to the 'maximum glaciation' of Kendall and Wroot, occupy the surface of a dissected plateau, and include the hilltop deposits at Rothwell, several small patches of highly-weathered boulder-clay near Garforth, Kippax, Fairburn, Darrington and elsewhere, and the gravels at Kellingley, Hambleton, etc.; they are found far beyond the southern limits of the area dealt with. They are not necessarily all of the same age. The newer drifts include the two low-level terraces of the Aire and Calder, the great mass of clays, etc., which fills the Vale of York up to about 25 feet O.D., and the solifluxion-products which have been sloughed off the hills and deposited in the valleys. The First (lower) terrace of the Aire and Calder is contemporaneous with much of the Vale of York drift just mentioned. The York-Escrick glaciation falls into the period of the newer drifts, as was pointed out by Kendall and Wroot (*op. cit.*, p. 525), but the exact correlation is not certain.

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[1] Kendall, P. F. and H. E. Wroot, *op. cit.*, pp. 454, 455.
[2] *Op. cit.*, pp. 465, 466.

The fact that the dreikanter are formed exclusively of materials derived from the denudation of the older drifts shows them to be later than these deposits. At Whitley (see p. 12) they barely antedate the newer drifts by which they are buried, and may be regarded as virtually contemporaneous with them. The same may be said of the solitary specimen found *in situ* at Castleford, at the base of the Second Terrace. Further, the unweathered state of the dreikanter which are so numerous in the solifluxion deposits south of the Aire and Calder suggests that Coombe Rock conditions (wet, sub-glacial) followed closely on the dreikanter-period, if indeed the two conditions did not overlap and alternate seasonally. Near Normanton these deposits appear to be contemporaneous with the Second (higher) terrace of the Calder; elsewhere their freshness suggests a later date. They appear to be earlier than some part of the later Vale of York drift, but their relations to this deposit are not too clear. The local equivalent of the Coombe Rock of the south of England has only recently been found on this side of the Vale of York, and limited investigation has not resulted in any clear subdivision. The great mass of it, which contains the dreikanter, is one of the latest deposits indicative of severe climate, and could only have been formed near the end of the last glaciation in Yorkshire.

Outside Yorkshire the effects of wind-erosion during Pleistocene or immediate post-Pleistocene times have been recognized in several parts of England.

In the Trent valley, near Nottingham, Professor Swinnerton contrasts the abundance of dreikanter on the surface of the older gravels with their apparent absence on the newer gravels which underlie the flood-plain alluvium.[1] The dune-sands east of the Trent north of Newark are attributed to the blowing away of sand from the surface of the newer gravels before the recent alluvium was deposited, and indicate wind-action of later date.[2] A recent search for dreikanter connected with these dunes yielded no results because pebbly surfaces which might have been exposed to this wind were not found. Wind-worn pebbles have been recorded near Scunthorpe by A. C. Dalton.[3]

The age of both the older and younger Trent gravels has been shown by Dr. Bernard Smith to be late Pleistocene.[4]

In the Birmingham district Professor Wills described dreikanter overlain by high-level sands, but again the age can only be recorded as late Pleistocene.[5]

Dr. Jackson's Lancashire specimens rested on boulder-clay and on the older terrace-gravels of the Mersey. They were overlain by deposits with Neolithic remains, and in the Wirral by the Lower

[1] Swinnerton, H. H., *op. cit.*, pp. 210, 211.
[2] 'The Geology of the Country around Ollerton' (*Mem. Geol. Surv.*), 1911, pp. 65, 66.
[3] *The Naturalist*, 1912, p. 235.
[4] Smith, Bernard, 'The Geology of the Nottingham District,' *Proc. Geol. Assoc.*, vol. xxiv (1913), pp. 235, 236. See also 'The Geology of the Country between Newark and Nottingham' (*Mem. Geol. Surv.*), 1908, pp. 73, 74.
[5] Wills, L. J., *op. cit.*

Forest Bed. The erosion period was considered to be early post-glacial.[1]

The sand-blasted surfaces in Leicestershire described by Dr. Raw (*op. cit.*) are taken to indicate wind-action later than the Chalky Boulder-Clay of the east Midlands; the interglacial age of a related occurrence near Birmingham is proved by the position of sand-blasted boulders beneath boulder-clay.

In Surrey the wind-faceted pebbles found by Mr. F. H. Edmunds lie in sandy drift; their disposition suggests a post-glacial date.[2]

In North Germany faceted pebbles are common in the 'Steinsohle', the basement bed of the younger Loess.[3] They appear to have been formed under steppe-conditions following the withdrawal of the last ice-sheet.

Other examples might be cited, but it is obvious from the foregoing that the conditions suitable for the production of dreikanter were widespread in Britain and Europe at some period or periods not remote from the close of Pleistocene times. One such period, at least, has left its mark on wide areas in the Vale of York. Later wind-action is indicated by the dune-sands of Lincolnshire, possibly also by the sand-blasted stones within the York and Escrick moraines. There is also evidence in the gravels of the Bawtry district which suggests another and earlier period of Pleistocene wind-erosion.[4]

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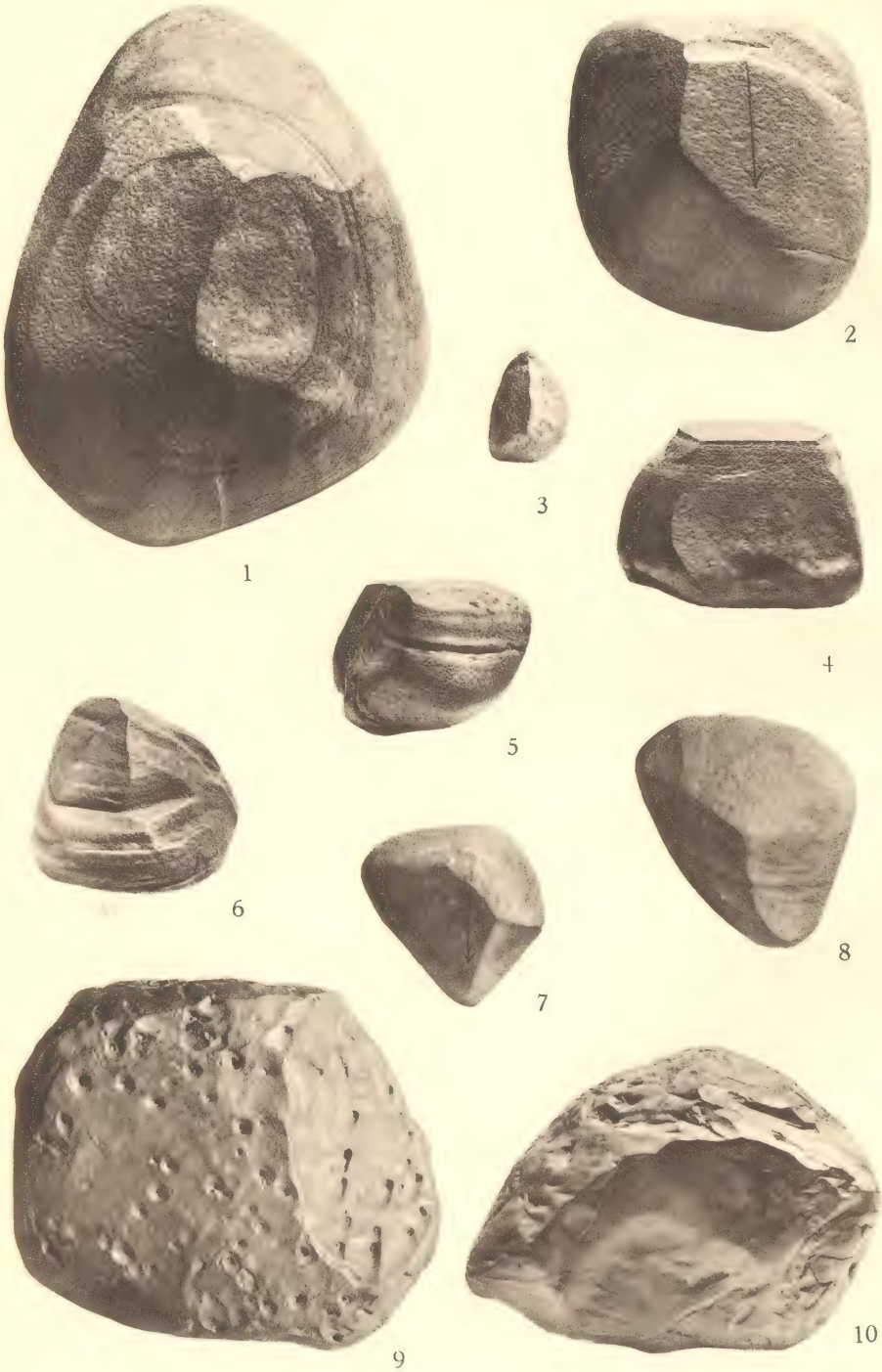
[1] Jackson, J. W., *op. cit.* See also Jackson, J. W., and O. T. Jones, 'Faceted Pebbles in the South Manchester District,' *ibid.*, vol. lxx (1925-26), pp. 125-132.

[2] 'The Geology of the Country around Aldershot and Guildford' (*Mem. Geol. Surv.*), 1929, p. 144.

[3] Several German authors are cited by Bather, F. A., *Proc. Geol. Assoc.*, vol. xvi, 1899-1900, p. 411.

[4] Wind-erosion may take place in the absence of a protective layer of vegetation, snow or water. It is not necessarily proof of desert or steppe climate.



WIND FACETED STONES FROM WHITLEY SAND PIT, NEAR SELBY

Description of Plate II

The specimens are preserved at the Geological Survey and Museum, South Kensington.

Fig.

1 & 2. Boulders of compact sandstone. In Fig. 1 the original shape is slightly modified by incipient facets. (The rings are colour-bands due to weathering.)

3. A large sandstone pebble showing 'brazil-nut' shape.

4-6. Cobbles of laminated sandstone showing wind erosion of bedding planes and faceting independent of bedding.

7 & 8. Compact sandstone cobbles with 'dreikanter' shapes.

9 & 10. Typical wind-erosion of ganister, showing large facets, probably due to fracture. Fig. 9 shows beautifully developed erosion of rootlet-holes.

All figures are 3/20 natural size except figures 2, 7 and 8 which are 1/10 natural size.

III.—ON THE WENLOCK CORAL *COENITES SERIATOPORA* (H. M. EDWARDS AND J. HAIME)

BY

K. P. OAKLEY, B.Sc.

Plate III.

INTRODUCTION

IN the course of a revision of the Wenlock Polyzoa it seemed desirable to elucidate the affinities of forms which have been variously referred by some authors to the Polyzoa, by others to the Anthozoa. A critical re-examination has accordingly been made of '*Alveolites*?' *seriatopora*, H. M. Edwards & J. Haime, a form which was regarded as a coral by Quenstedt, and Bassler, although relegated to the Polyzoa by Lindström, Vine, Hennig, and Woods.

On the evidence of the internal structure this form can now be referred with confidence to the Anthozoa, and it is here provisionally placed within the genus *Coenites*. As the morphology of *Coenites* is at present under consideration by Dr. Stanley Smith, it would be out of place in the present connexion to discuss the characters of the genus. It is clear from its structural plan and mode of budding that it is a genus of Tabulate coral, and that its relationship is with such forms as *Pachypora* and *Striatopora*. It appears to represent, in fact, a specialized dendroid off-shoot of the Favositid stock.

I wish to thank Mr. A. G. Brighton of the Sedgwick Museum for the loan of type-material, and Dr. Stanley Smith and Dr. H. H. Thomas for helpful discussion on various points.

Coenites seriatopora (H. M. Edwards & J. Haime)

PLATE III, figs. 1, 2, 3, 3a.

1839. *Millepora repens* (partim) W. Lonsdale, in Murchison's 'Silurian System,' pl. 15, fig. 30a.

1851. *Alveolites*? *seriatopora* H. M. Edwards & J. Haime, 'Monographie des Polypiers Fossiles des Terrains Palaeozöiques,' *Arch. Mus. Hist. Nat.*, vol. v., p. 260–1.

1855.[1] *Alveolites*? *seriatoporoides* H. M. Edwards & J. Haime, 'A Monograph of the British Fossil Corals,' pt. v, *Palaeont. Soc.*, pp. 263-4, pl. lxii, figs. 2, 2a.

1878. *Chaetetes seriatoporoides* F. A. Quenstedt, 'Petrefactenkunde Deutschlands,' vol. vi, p. 84, pl. 146, figs. 31, 32.

1885. *Cladopora seriatoporoides* G. R. Vine, *Proc. Yorks. Geol. & Polytech. Soc.*, N.S., vol. ix, p. 244.

1888. *Cladopora seriatopora* G. Lindström, 'List of the Fossil Faunas of Sweden, pt. 2, Upper Silurian,' Stockholm, p. 16.

[1] The date of issue of the Palaeontographical Society's volume for 1854 was correctly given on the cover as 1855, but incorrectly on the title page of Edwards' and Haime's monograph, as 1854.

1891. *Spiropora? seriatoporoides* H. Woods, 'Catalogue of the Type Fossils in the Woodwardian Museum, Cambridge,' p. 45.
1906. *Coenites repens* (partim) A. Hennig, 'Gotlands Silur-Bryozoer,' 2, *Arkiv för Zoologi*, vol. 2, no. 10, p. 27.
1915. *Alveolites? seriatopora* R. S. Bassler, *Bull. U. S. Nat. Mus.*, no. 92, p. 28.

Synonymy.—In their English work (1855) Edwards and Haime, for some unknown reason, changed the trivial name from *seriatopora* (which they introduced in their French monograph, 1851) to *seriatoporoides*. The earlier name is accompanied by a sufficiently precise description to make it valid, and it therefore takes precedence over the later name. Although no figure accompanied the 1851 description, the synonymity of the names is substantiated by the fact that the authors give *A? seriatopora* in their list of equivalents of *A? seriatoporoides*. They also include in their list of synonyms (1885, p. 260) *Millepora ramis cylindraceis*, etc. of Linnaeus.[1] From Linnaeus' diagnosis and figure, however, the form in question would appear to be *Coenites repens* Hisinger, forma *seriata* Hennig. The triangular form of the apertures would certainly exclude it from *C. seriatopora*.

Hololectotype (here chosen).—Fletcher Collection, Sedgwick Museum, Cambridge; Specimens A. 6754 a & b. Wenlock Limestone, Dudley. Plate III, figs. 3, 3a.

The lectotype consists of what are taken to be halves of an imperfect, branched corallum. The two parts appear united in the figure given by Edwards and Haime (*op. cit.*, 1855, pl. lxii, fig. 2). It is possible that the figure is a partial reconstruction as no obvious recent fractures can be detected on the actual pieces. The corallum appears laterally reversed in the original reproduction on account of the lithographic process employed.

The branches of the corallum are preserved to a height of about 16 mm. above the assumed proximal bifurcation. Distally the branches fork twice. In the case of the one branch the most distal bifurcation is in a plane set at an angle to that of the others. The branches vary in diameter from 2.6 mm. proximally, to 1.7 distally.

Diagnosis.—Based on the lectotype, on specimens collected from the Wenlock Limestone at Farley Dingle and Benthall Edge, Shropshire, and on topotype material.

Ramose *Coenites;* branches cylindrical with narrow axial portion composed of a few vertical corallites from which the rest diverge. The lateral corallites are sharply deflected at a certain distance from the imaginary axis, and so open nearly at right-angles to the surface. Circular calicular openings in alternating vertical series; lumen of corallites considerably reduced distally owing to thickening of their walls by stereome.

Description.—External characters. The corallum is typically

[1] Linnaeus, C., 'Henrici Fougt . . . . Dissertatio Coralliis Balticis,' *Amoenitates Academicae*, vol. i., 1745, pt.iv, p.98, fig. 15.

ramose, consisting of cylindrical or sub-cylindrical branches varying from 1.5 to 2.6 mm. in diameter; the branching is commonly dichotomous, the angle of bifurcation varying from 90° to 120°, the average being slightly over a right-angle. Distally there is a tendency for the branching to be multiplanar. The external surface is smooth except for the calicular openings, which are circular, and arranged in irregular vertical series showing a marked tendency to alteration. The apertures are separated by intervals of up to 0.6 mm. The size of the apertures is subject to considerable variation, being dependent on the development of stereome, and on the maturity of the corallum. They vary in diameter from 0.2 to 0.6 mm. The calices are cylindrical and emerge at right-angles to the surface of the branch. On the external surface the actual boundaries between the corallites are obscure.

Internal characters. The corallites vary in diameter from 0.1 mm. in the axial region, to between 0.4 and 0.6 mm. where they open on the surface. A small number of corallites, usually not more than ten or twelve at any particular level, run parallel to the axis in the central part of the corallum, and constitute the axial region. Each of these axial corallites runs a vertical course for 3 to 7 mm. before dividing. It may happen that only two are visible at any particular level in a longitudinal section, in which case their bounding wall has the appearance of an axial lamina. In an average-sized specimen the axial region is about 0.3 mm. in diameter. The axial corallites, before dividing, bud off numerous lateral corallites along their whole length. These, after diverging at an angle of about 30° for a short distance (in what may be termed the peri-axial region), turn abruptly outwards and follow a course which is nearly at right-angles to the axis; the angle which the distal ends of the corallites make with the surface varies between 70° and 90°. If each axial corallite is followed upwards it is found that it eventually divides, one bud branching off as a lateral corallite, and the other extending vertically as a new axial corallite. The number of vertical rows of calices presumably corresponds to the number of axial corallites, since the lateral corallites, which arise from them, have never been observed to divide.

The original corallite walls are extremely thin and show the minutely moniliform structure which is observable in other species of *Coenites*.[1] They are reinforced by a lining of stereome (lamellar sclerenchyme). The stereome laminae are slightly oblique to the surface of the branch, and so that in longitudinal sections the stereome presents the same vertically laminated appearance as in the Devonian coral ' *Trachypora*."[2]

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[1] Cf. Hennig, A. *op. cit.* 1906, p. 32, fig. 20.

[2] Cf. Nicholson, H. A., " On the Structure and Affinities of the ' Tabulate Corals ' of the Palaeozoic Periods," 1879, pl.v, fig. 3b.

In transverse sections of the branches of the corallum the stereome appears concentrically zoned as in '*Trachypora*'; festooning of the concentric zones in the region of the calices indicates that the stereome laminae are vaulted. In the axial zone and in the proximal parts of the lateral corallites the stereome is extremely thin. Distally, however, after the lateral corallites have changed their direction of growth and widened out, their walls become thickened to a remarkable extent, particularly on the upper[1] surface of each calice, where the stereome attains a thickness of up to 0.3 mm. The stereome may contract at the actual margins of the calices, so that the apertures are sometimes almost in contact (Pl. III, fig. 3, proximal region of left-hand branch), although as a general rule they are widely separated by the stereome matrix.

Thin, horizontal, and complete tabulae are developed in the axial region of the corallum. Relatively large round mural pores occur sporadically but are rarely seen.

Transverse sections of the corallum are distinctive on account of the wide peripheral zone of stereome (Pl. III, fig. 2). There is an inner region, comprising axial and peri-axial zones, from 0.5 to 0.7 mm. in diameter. The axial corallites tend to show a radially elongate cross-section which is clearly defined owing to the absence of stereome. Those in the peri-axial zone, however, are less clearly defined on account of both their obliquity and the thickening of their walls by stereome, and often present a cordate outline. Some 15 to 20 corallites appear in cross- and sagittal-section in this inner region. Peripherally there is a wide zone of stereome penetrated by marginal inlets, corresponding to the distal ends of the lateral corallites.

Affinities.—With the exception of the difference in form of the calicinal apertures, this species agrees closely in all essential structural features with the genolectotype[2] of *Coenites* (*C. juniperinus* Eichwald 1829). There is agreement in the general habit, order of size of the corallites, mode of budding, and form of the stereome. In view of the apparently close relationship between the form under discussion, and *Coenites* of the *repens* species-group, it is thought advisable for the present to include it within *Coenites*, although it is considered that the differences which separate it from the syntypes of that genus are near the legitimate limits of generic range.

The two most important distinguishing characters of the species are the abrupt change in the growth-direction of the lateral corallites, and the sudden increase in the diameter of the latter consequent on that change. However, even these characters are subject to variation, and there is a gradation towards the condition seen in *C. repens* in which the lateral corallites widen out gradually, and follow a steadily oblique course to the surface. The occurrence of an axial zone composed of vertical corallites from which the rest

[1] 'Distal' in Hennig's description.
[2] Bassler, R. S., *op. cit.*, 1915, p. 254.

diverge, suggests a closer affinity with *C. repens* than with *C. juniperinus*, the latter being distinguished in longitudinal sections by the absence of any distinct axial zone. In the light of this suggestion, the fact that in one variety of *C. juniperinus*[1] the corallites have been observed to bend sharply outwards near the periphery, so as to open at right-angles to the surface, possibly indicates that this particular condition was the result of a definite trend which expressed itself in two species-groups. The same trend is manifest in species of *Pachypora*. *P. cristata* (Edwards & Haime) might be regarded as a homoeomorph of *C. seriatopora* in this respect[2].

Specimens of *C. repens* in a weathered condition (? the forma *seriata* of Hennig's description[3]) often resemble *C. seriatopora*, but like normal specimens of *C. repens*, are readily distinguished, (i) by the obvious obliquity of the calices, (ii) by the less regular, rather undulating corallite walls, and (iii) by the absence of any clear division into peri-axial and peripheral zones. In *C. repens*, moreover, the stereome layer gradually increases in thickness as it is traced from the proximal part of a corallite to its distal termination, whereas in *C. seriatopora*, on account of the change in the direction of growth of the corallites, the stereome appears to be greatly augmented in the peripheral region. Externally *C. seriatopora* is readily distinguished from the normal *C. repens* by its direct and perfectly circular calices.

Occurrence.—Coenites seriatopora is recorded by Vine[4] from the Wenlock Shales (Coalbrookdale and Tickwood Beds, but not apparently from the Buildwas Beds). It occurs quite commonly in the Wenlock Limestone, and has been found at Dudley (in the Nodular Division), Wenlock Edge, and Benthall Edge. Lindström[5] records *Cladopora seriatopora* (E. & H.) from the *c* beds of the Gotlandian of Sweden; the *c* division has been correlated by Hede[6] with the Lower Ludlow Shales.

Edwards and Haime[7] refer to the recognition of the species in Silurian rocks at Bear Grass Creek, near Louisville, Kentucky. The record is of doubtful value as the identification can only have rested on external appearance. The form in question was probably *Cladopora multipora* Hall[8]. According to Bassler[9] *Alveolites? seriatopora* has not been recognized as an American species.

General Remarks on Coenites.—Many species of *Coenites* closely resemble certain polyzoans in general appearance. *C. seriatopora* is perhaps the most striking example of this

[1] Nicholson, H. A., *op. cit.*, 1879, pl. vi. fig. 5a.
[2] *Ibid.* pl. v., fig. 1a.
[3] Cf. Hennig, A. *op. cit.*, 1906, pl. 6, figs. 3, 5.
[4] Vine, G. R., *op. cit.*, 1885, p. 244.
[5] Lindström, G. *op. cit.*, 1888, p. 16.
[6] Hede, J. E., 'Gotlands Silurstratigrafi,' *Sveriges Geol. Undersök.*, series c, vol. 14, no. 7, p. 87.
[7] Edwards, H. M. & J. Haime, *op. cit.*, 1851, p. 260.
[8] Nicholson, H. A. & G. J. Hinde, *Canadian Journal*, N. S., vol. xiv, 1873, p.148.
[9] Bassler, R. S., *op. cit.*, 1915, p. 28.

convergence. In fact, until a detailed examination of this form was made it was thought that one might be dealing with a polyzoan closely approaching the *Coenites*-type of coral through convergence, instead of *vice versa* as is actually claimed to be the case. In view of this, and of the fact that Hennig referred *Coenites* to the Polyzoa, a few remarks on the main reasons for the rehabilitation of the genus within the Anthozoa may not be wholly irrelevant.

The only polyzoans to which the *Coenites*-type bears any resemblance in internal structure are the Cyclostomata, more particularly the family Entalophoridae, to which, in fact, Hennig regarded his Coenitidae as closely allied[1]. A critical examination of the morphology of *Coenites* shows, however, that the resemblance is purely superficial. In the first place *Coenites* is characterized by large mural pores; these are particularly well developed in *C. juniperinus* Eichwald[2]. Although the walls of Cyclostomatous Polyzoa are minutely perforate, and the zooecial walls in the Ceramoporidae may be perforated by relatively large irregular pores[3], the presence of large, well-defined circular mural pores, perforating secondary calcareous tissue, appears to be peculiar to Tabulate corals. In the second place the mode of budding in *Coenites* differs from that found among the group of Polyzoa to which the Entalophoridae belong, in that occasionally a bud arises which is continuous proximally with the parent ' cell '; that is to say in longitudinal sections a ' cell ' wall appears to have been interpolated[4], instead of bifurcating from an existing wall. Whereas both types of gemmation occur among Tabulate corals, the interpolation-type is apparently unknown among Cylostomatous Polyzoa.

Another important issue centres around the occurrence of secondary calcareous tissue within the ' cells '. Among the Polyzoa the development of secondary calcareous tissue, resembling in any way the stereome of corals, is confined to the Cryptostomata, with which, however, *Coenites* has no essential features in common. From its histology it is quite clear that the secondary calcareous tissue in *Coenites* is of the normal anthozoan type (stereome); in fact indistinguishable from that developed in *Pachypora,* and allied genera.

In species of the *C. juniperinus*-group the calicinal apertures are constricted by tooth-like projections of sclerenchyme. There are commonly two of these on the lower (' proximal ') margin of each aperture; they form a bicornute process which Hennig regarded as homologous with the *lunarium* of the Ceramoporoid and Fistuliporoid Polyzoa. Although the resemblance is

[1] Hennig, A., *op. cit.*, 1906, p. 26.
[2] Nicholson, H. A., *op. cit.*, 1879, pl. vi, fig. 5a.
[3] Bassler, R. S., 'The Early Palaeozoic Bryozoa of the Baltic Provinces,' *Bull. U.S. Nat. Mus.*, no. 77, 1911, p. 93.
[4] Nicholson, H. A., *op. cit.*, 1879, pl. vi, fig. 5a.

strikingly close in some cases[1], the fact that as many as six projections may occur around a single aperture[2], eliminates the possibility of the homology suggested by Hennig. The polyzoan lunarium is a feature which is particularly constant in character and which is confined to the dorsal margin of the zooecial aperture. The processiform structures in *Coenites* are formed of the normal stereome which lines the calices, and may be considered as homologous with the ' spiniform septa ' which occur in the calices of ' *Trachypora* ' and related genera[3].

It may be pointed out in conclusion that through the confusion of these minute Tabulate corals with Polyzoa, the abundance of the latter in the Silurian limestones of this country has been unwittingly exaggerated. A case in point is the so-called ' bryozoan '[4] reef-facies of the Woolhope Limestone at Old Radnor[5], which would have more claim in fact to be termed a coral facies, since the dominant rock-building organisms are not Polyzoa but species of *Coenites*. For the same reason there has been a tendency to overstate the polyzoan content of much of the Wenlock Limestone of the type area, where *Coenites* is actually far more abundantly represented than Polyzoa.

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[1] Hennig, A., *op. cit.* 1906, pl. vi, fig. 8b. Cf. Bassler, R. S., *op. cit.*, 1911, text-fig 32b.

[2] Nicholson, H. A., *op. cit.*, 1879, pl. vii, fig. 1c.

[3] Nicholson, H. A., *op. cit.*, 1879, pl. v, 3b.

[4] *i.e.* polyzoan.

[5] Garwood, E. J. & E. Goodyear, ' On the Geology of the Old Radnor District,' *Quart. Journ. Geol. Soc.* vol. lxxiv, 1918, p. 18.

COENITES SERIATOPORA. (Edwards & Haime)

Description of Plate III

Coenites seriatopora (Edwards and Haime)

Fig.

1. Longitudinal section through axis of unbranched corallum, × 14. Geol. Surv. Coll. 58301. Wenlock Limestone, Farley quarry near Much Wenlock.
2. Transverse section through branch of corallum, × 37. Geol. Surv. Coll. 58302. Wenlock Limestone, Farley quarry near Much Wenlock.
3. Hololectotype, × 3. Sedgwick Museum A.6754a and A.6754b. Wenlock Limestone, Dudley.

3a. Portion of hololectotype, × 6.

IV.—ON A BORING AT OXENDON, NORTHAMPTONSHIRE

BY

BERNARD SMITH, M.A., Sc.D., F.R.S.

THE interest of this boring which was put down for water at Oxendon Hall, Great Oxendon, Northamptonshire, lies in the fact that the old floor, presumably of Pre-Cambrian Rocks, was encountered beneath an attenuated representative of the Keuper Marls, at a depth nearly the same as that at which it was reached west of Orton Village nearly five miles distant.

We are indebted to Major C. R. Bates, for whom the work was done, for particulars of the strata, and for fossils and samples of the cores that were forwarded for identification from time to time.

The record is approximately as follows :—

Bore for Water, Oxendon Hall, Northamptonshire

One-inch map New Series 170. Site about ¾ mile south of Great Oxendon ; 2¾ miles south of Market Harborough, Leicestershire, or 5 miles west-north-west of Orton, Northamptonshire. Lat. 52° 26′ 8″, Long. 0° 55′ 10″ W. Height of surface above O.D. about 385 ft. Sunk by W. Mansfield & Co., Liverpool.

			Approximate Thickness		Depth	
			Ft.	In.	Ft.	In.
Upper & Middle Lias (at least 104 ft.)	Proved in wells	Brown clay	4	0	4	0
		Softish blue clay, harder downwards	9	0	13	0
		Marlstone, rock-bed	2	0	15	0
	Blue clay and shale with shells near base ...		89	0	104	0
Lower Lias (574 ft.)	Blue shale with shells ; harder at 202-5 ft. ...		416	0	520	0
	Blue shale with thin harder bands of a few inches up to 5 ft., with shells		158	0	678	0
Rhaetic (18 ft.)	Thin fine grit or conglomerate with pyrites ... ... say		0	3	678	3
Pteria	Pale limestone with shells ... ... (No black shales observed)		17	9	696	0
Keuper (64 ft.)	Green shale		8	0	704	0
	Chocolate coloured marl, "a few feet," ... ... say		3	0	707	0
	Greenish and pale brown shale or marl ...		9	0	716	0
	Fine grained marlstone unevenly bedded and silty		2	0	718	0
	Greenish marl, part silty, no cores ...		18	0	736	0
	Green and grey sandstone, part marly ...		2	0	738	0
	Greenish marl with harder silty bands ...		16	6	754	6
	Red marl, part silty with few quartz grains		1	6	756	0
	Greenish grey marl, part silty & nodular ...		4	0	760	0
Pre-Cambrian	Hard broken rock ' quartz-felsite ' ...		50	0	810	0

A considerable quantity of water under hydrostatic pressure was met with in the Lower Lias at 400 feet, and at 440 to 500 feet, but the latter proved useless as it brought with it great volumes of mud, which could not be dealt with successfully except by tubing off. The water found at lower depths, though sufficient in quantity, proved to be saline. A potable supply was obtained eventually from two 4-ft. diameter wells, 20 ft. deep, dug on the site of the bore. They yielded 4,000-5,000 gallons per day from the Middle Lias.

The Upper Lias is apparently very thin here, because the rock in the wells at 13-15 ft. seems to represent the Marlstone Rock Bed. From this Mr. Chatwin identified the fossils *Pseudopecten aequivalvis* (J. Sowerby), *Oxytoma inaequivalvis* (J. Sowerby), and *Protocardia truncata* (J. de C. Sowerby), and the boring was still in the Middle Lias at 104 ft., for the late Dr. F. L. Kitchin, reporting on a specimen from that depth, states that it may be regarded as " low in the Margaritatus Zone of the Middle Lias ", specimens from the next 30 ft. being presumably in the Capricornus Zone of the Lower Lias. Dr. Kitchin also recognized *Arnioceras semicostatum* (Young and Bird) from a depth of 535 ft.; and expected that there would be at least 100 ft. of Lower Lias beneath that horizon.

Below this the specimens down to about 678 ft. were typical of the normal Lower Lias which comes to outcrop in Leicestershire; but the pale rock—superficially resembling Carboniferous Limestone was an abnormal type of the White Lias, which is usually a smooth and fine-grained limestone, or even calcite-mudstone. The abnormality was emphasized by the occurrence, at or near its top, of a thin bed of polygenetic grit or fine conglomerate.

Upon the receipt of these latter specimens, long before the completion of the boring, it was suggested that in late Triassic times there was probably an old land surface undergoing denudation near at hand, comprising intrusive and volcanic rocks comparable with those of Charnwood Forest, and possibly also Carboniferous Limestone.

For a few feet beneath the White Lias very little core was recovered and no black *Pteria contorta* shales, characteristic of the Rhaetic of Leicestershire and Northamptonshire (Billesdon, Rugby, Beeby, etc.), were detected, but the division was underlain by green shales which we have classed with the Tea Green Marls of the Keuper. From samples submitted they are not quite typical of the Tea Green Marls of the Leicestershire outcrops; they are more laminated and more silty. At Orton (see below) beds that may be similar were classed by Beeby Thompson as equivalents of the black *Pteria* shales of the Rhaetic which were actually proved beneath green shales in the Gayton bore, 5 miles south-west of Northampton[1].

The remainder of the Keuper, of which only 56 ft. was present,

[1] Eunson, H. J., 'The Range of the Palaeozoic Rocks beneath Northampton,' *Quart. Journ. Geol. Soc.*, vol. lx, 1884, p. 486.

instead of about 700 ft., was abnormal also (as it is still more pronouncedly at Orton), and contrasts with that of districts where it is fully developed, as near Leicester. It comprised more green marl of a bedded and silty type than is usual, with calcium and magnesium carbonates, and may be compared with some of that which fringes and overlaps Charnian outcrops, as at Enderby, Leicestershire (see T. O. Bosworth, 'Keuper Marls around Charnwood', 1912, p. 71).

The occurrence of about 3 ft. of typical chocolate marl at its top is also significant, since it implies that the Tea Green Marls—a definite 25 to 30 ft. lithological unit which normally overlies the thick red and chocolate Keuper Marls—may here be represented only by the overlying 8 ft. of 'green shale'. The usual gypsiferous horizon which occurs within the upper 60 ft. of the Keuper Marls is apparently wanting.

To sum up: the deposits of Rhaetic and Keuper age in this boring are definitely abnormal types, which one must attribute to their formation as shore-line sediments on the flanks of and close to a land mass or island of old rocks. These old rocks consisted in part of various Pre-Cambrian volcanic types, upon one of which—the quartz-felsite (determined by Dr. H. H. Thomas)—they actually rest at this point, and perhaps in part of rocks of Carboniferous age. The general 'greyness' or greenish tint of the Keuper may be ascribed to three causes. Firstly to the silty nature of the deposits; secondly to the presence at the time of relatively fresh, moving, and comparatively shallow water at this locality (*cf.* the scarcity of gypsum), and lastly perhaps to the action of reducing acids derived from the vegetation of the neighbouring land.

A *précis* of the Orton Bore, Northamptonshire, is given opposite for comparison, the lower part only being in detail (see 'The Water Supply of Bedfordshire and Northamptonshire', *Mem. Geol. Surv.*, 1909, pp. 141-2[1]).

[1] Also Eunson, H. J., *op. cit.*, pp. 491-3.

Orton Boring, Northamptonshire

Site alongside The Slide Brook, 1,400 yds. W. by S. of Orton Church.

Height of surface above O.D. 374.17 ft. Classification by Beeby Thompson.

			Thickness Ft.	In.	Depth Ft.	In.
Upper Lias		... ...	48	0	48	0
Middle Lias		... ...	87	0	135	0
Lower Lias		... ...	531	0	666	0
Rhaetic 22 ft.	White Lias 12 ft. 3 in.	Junction bed between Lias clay and limestone below ...	0	6		
		White limestone, fissured, containing large crystals of calc-spar, and some iron pyrites	3	6	670	0
		Conglomerate of small pebbles, some of limestone, cemented by iron pyrites	0	3		
		White, sandy limestone ...	6	9	677	0
		Conglomerate of small fragments of quartz-porphyrite and some iron pyrites ...	1	3	678	3
	Equiv. of Black Shales 9 ft. 9 in.	Green (or grey ?) shale ...	0	6		
		Band of grey sandy marl ...	1	9		
		Green shale with light and dark bands	7	6	688	0
Trias 27 ft. 6 in.		Coarse, grey sandstone Breccia of fragments of quartz-porphyrite or dacite in a green sandy matrix ...	24	0		
			3	0	715	0
		Old land surface at 340.83 feet below sea-level				
Archaean		Quartz-porphyrite or quartz-felsite with eroded surface. Distinct cleavage in the rock at an angle of 18° with the axis of the core ...	74	0	789	0

V.—ON A BORE REACHING PALAEOZOIC STRATA AT BUSHEY, HERTS.

BY

F. H. EDMUNDS, M.A.

WITH NOTES ON THE PALAEOZOIC FOSSILS

BY

C. J. STUBBLEFIELD, PH. D., A.R.C.SC.

AND ON WATER ENCOUNTERED

BY

F. KENNETH SINCLAIR, B.SC., A.M.INST.C.E.

Text-figure 1.

DURING the latter part of 1934 a percussion bore was put down from the bottom of a well in Chalk at the Bushey Waterworks of the Colne Valley Water Company, with the object of penetrating the Gault in the hope of entering the Lower Greensand, and so tapping a new source of water.

The Geological Survey is indebted to Mr. F. Kenneth Sinclair, B.Sc., A.M. Inst. C.E., the Chief Engineer of the Colne Valley Water Company, for the record of the journal of the bore, and for interesting details given below (p. 36) concerning the behaviour of the water encountered.

It was found that the Lower Greensand is absent under the site, and that Gault rests directly on Palaeozoic rocks.

The original well dates from 1885 when a shaft 6ft. in diameter was sunk to a depth of about 50 ft., from the bottom of which a bore, of 18 in. diameter was made to —288 ft. O.D., and thence of 15 in. to about —400 ft. O.D. The surface level of the site is about 200 ft. O.D.

It should be noted that in an account of this well by W. Verini in *Trans. Herts. Nat. Hist. Soc.*, vol. iv, 1888, p. 116, there is an error of 100 ft., the depth being given as 700 ft., *i.e.* about —500 ft. O.D. The account given by Whitaker in ' Water Supply of Buckinghamshire and Hertfordshire ', (*Mem. Geol. Surv.*), 1921, pp. 197-199, was largely taken from this record, and repeats the error. It is obvious, however, that Whitaker was puzzled by the journal of the bore, and was in considerable uncertainty as to the classification of the Chalk. He bases the tentative classification given in the Water Supply Memoir on an examination of specimens by W. Hill, but records that Jukes-Browne was inclined to doubt the position given to the Chalk Rock, and thought that it should be rather at a bed of hard grey rock about 195 ft. down, but even then Jukes-Browne considered the combined thickness of the Middle and Lower Chalk as being too great.

The thicknesses given by Whitaker are quoted in ' The Geology of the Country around Hertford ', (*Mem. Geol. Surv.*), 1924, p. 8, with a note to the effect that there is some doubt as to the thickness of the Middle Chalk.

There is no direct evidence as to where the extra 100 ft. was added to the journal, but there is strong presumptive evidence that a bed of ' hard chalk with little clay (with thin layers of blue clay) ' all included as part of the Middle Chalk and given as 215½ ft. thick, was actually but 115½ ft. thick. There is little doubt that Jukes-Browne was correct in placing the base of the ' Chalk Rock ' at 195 ft. down, the ' Chalk Rock ' of Whitaker's classification being the ' Top Rock ' at the top of the *Holaster planus* Zone. Further, the Blue Clay at 437½ ft., in Verini's and Whitaker's records is the Plenus Marl and was correctly taken by Whitaker as being the top of the Lower Chalk.

The ' dark green sand ' near the base of the original bore is the Chloritic Marl. Thus the Lower Chalk is 246 ft. thick.

Later work on the Chalk of South-East England has lent weight to Jukes-Browne's criticism of the estimate of the combined thicknesses of the Lower and Middle Chalk at Bushey; but while the thickness of 255 ft. assigned to the Lower Chalk is reasonable, though full, a thickness of 244 ft. for the Middle Chalk (*i.e.* chalk between 194½ ft. and 436 ft. in Verini's record) is considerably in excess of any other known thickness over the whole of the Chalk outcrop.

The recent continuation of the borehole has shown the absence of Upper Greensand, a usual feature of the district, and has proved Gault to a depth of 899 ft., below which came a series of red and purple sands and clays, with a grey fossiliferous limestone at 980 ft. below the surface.

The full record and classification of the strata proved in the combined 1885-1934 shaft and bore may therefore be considered to be as follows:—

Bore for Water, Bushey

Site:—The Colne Valley Water Company's Waterworks, Aldenham Road, Bushey, Herts.

One-inch New Series Geological Map, Sheet 256. Six-inch Geological Map Sheet: Herts., XLIV, N.W. Latitude: 51° 39′. Longitude: 0° 22′ 50″ W. Height of Surface above Ordnance Datum: 196.5 ft. Shaft of 6 ft. diameter: originally 50 ft., deepened to 66 ft. Bored to 980 ft.

Strata		Description of Rock	Thickness Ft.	Depth Ft.
Upper Chalk		Soil	5	5
		Rotten chalk with bands of flint ...	42	47
		Soft chalk with seven layers of flint, two 12 in. thick, the rest 6 in. ...	44½	91½
		Hard Chalk, with four layers of flint, one 18 in. the rest 6 in.	26	117½
		Soft Chalk with a 12 in. and a 6 in. layer of flint	43½	161
	Top Rock	Hard grey chalk	8	169
		Soft chalk	3½	172½
		Very hard blue bind	6	178½
	Chalk Rock	Hard rock chalk	16	194½
Middle Chalk 141½ ft.		Blue clay	1	195½
		Hard chalk with thin layers of clay	25	220½
		Hard chalk with little clay ...	115½	336
Lower Chalk 255 ft.	Plenus Marl	Blue clay	1½	337½
		Hard chalk	4½	342
		Soft chalk with little clay	80	422
		Hard dark chalk with clay ...	50	472
		Dark chalk marl	114	586
	Chloritic Marl	Dark green sand	5	591
Upper Gault 308 ft.		Blue clay, which became gradually darker in colour at greater depth	282	873
		Dark blue clay with phosphatic nodules and fossils	26	899
Devonian		Mauve-red mottled sandy clay ...	3	902
		Mottled sandy shale	3	905
		Dark mauve and black shale, some with greenish tinges	6	911
		Hard black shale	4	915
		Coarse black sand	3½	918½
		Mottled mauve clay	8½	927
		Fine dark grey clayey sand ...	4	931
		Mottled mauve-grey clayey sand ...	2	933
		Light grey clay	1	934
		Dull yellow plastic clay	2	936
		Red sandstone and clay	17	953
		Yellow clayey sand	2	955
		Red sandstone and light grey clay	1	956
		Light blue clay with seams of sand	3	959
		Grey sand and clay	1	960
		Clean grey sand	1	961
		Light blue clay with seams of sand	5	966
		Red sandstone and some blue-grey clay	1	967
		Solid red sandstone	12	979
		Very hard blue-grey siliceous limestone with fossils ... proved to	1	980

The borehole was put down by Messrs. George Stow, Newport, Mon.

The bottom few feet of the Gault yielded fossils, including ammonites which have been identified by Dr. L. F. Spath as *Euhoplites sp.* (*lautus* group) and *Hysteroceras sp.*

These are Upper Gault forms, and their position in the sequence indicates that the Lower Gault is absent, and thus gives an additional example from underground of the overlap described by Kitchin and Pringle[1].

No fossils were obtained from the beds between 899 ft. and 979 ft., but the lowest foot yielded, in addition to several small fragments, a block of grey calcareous sandstone about 4½ in. cube. Dr. C. J. Stubblefield's report on this material is as follows.

" The block of grey calcareous sandstone from a depth of 980 ft. showed about 4 square inches of adherent shaly bedding surface which, on being washed, revealed débris of marine fossils. Small crinoid stem-columnals (0.5-2.0 mm. in diameter) of two types are present, one of pentagonal outline with concave sides, the other being circular; with these occur a few minute arm-ossicles. Interspersed among these are black, possibly phosphatic, casts of small probably immature gastropods—a few with diameter up to 1.5 mm. having wide spiral angles, others (length up to 1 mm.) being more turreted, but none showing more than two whorls. There are, however, a few small black internal casts of a species of *Tentaculites;* two of these are well preserved, the larger, 1.5 mm. in length and 0.2 mm. diameter, shows 15 annulations in a length of 1 mm.; the smaller (about 0.5 mm. in length) gives a similar ratio. Several fragments of poorly preserved brachiopod shells of Rhynchonellid and Chonetid types complete the picture presented by this shaly surface.

The splitting of the block with a hammer revealed a crystalline crinoidal limestone, grey-brown in colour, containing pebbles (up to 40 mm. in diameter) of grey-green compact limestone, also smaller fragments (2 mm. in diameter) of iron oxide in the form of red haematite or brown limonite which sometimes had infilled the shells of small gastropods. The crinoidal limestone passed vertically into a grey-green sandy limestone containing some organic fragments of which Professor D. M. S. Watson, F.R.S., writes " they appear to be actually of vertebrate origin but are completely undeterminable. On the whole they are less unlike fragments of early Acanthodian fish than parts of any other animal." This grey limestone also contains poorly preserved Rhynchonellids, probable Lingulids, and a doubtfully named *Hormotoma.*

The evidence of precise age for this rock is not of a very positive nature. The presence of undoubted *Tentaculites* rules out post-Devonian time. The grey-green sandy limestone lithology is comparable with a rock-type found within the basal twenty feet of the core-boring at Little Missenden described by Strahan and Pringle[2] as of Upper Ludlow Age and later by Straw[3] as of late

[1] On the overlap of the Upper Gault in England and on the 'Red Chalk' of the Eastern Counties. *Geol. Mag.*, 1922, pp. 156-200.
[2] 'Summary of Progress' for 1915 (*Mem. Geol. Surv.*), 1916, pp. 43-46.
[3] *Ibid.*, for 1932, pt. II, 1933, pp. 112-142.

Downtonian or Lower Devonian age. The presence of black phosphatic (?) casts of small gastropod shells can also be seen in some of the Little Missenden rocks of this age, associated, as here, with marine invertebrates and Acanthodian fish. The limited material available from the Bushey percussion-bore precludes much comparison with the array of richly fosssiliferous cores collected from Little Missenden, but it may be remarked that the *Tentaculites* specimens from Bushey resemble early stages of the species named by Straw as *Tentaculites annulatus* Schlotheim, and that the imperfectly preserved Rhynchonellids may well be a species of *Camarotoechia*, possibly *C. glomerosa* McLearn, recorded from Little Missenden. The presence of other genera known from Little Missenden is suggested amongst the fossils found at Bushey; a complete list of the fauna found at 979 ft. in the present borehole is:—

Crinoid remains (circular and pentagonal stem-columnals)
Hormotoma?
Tentaculites *cf.* annulatus *Schlotheim.*
Immature gastropods (flat and turreted spirals)
Chonetes?
Lingula?
Rhynchonella (Camarotoechia?) sp.
Fish remains (Acanthodian?)

The balance of available palaeontological evidence points to a tentative correlation of the Bushey limestone with the Downtonian or Lower Devonian strata at Little Missenden rather than with other strata; the absence of diagnostic ostracods may well be due to the limited amount of material available."

Mr. Sinclair's notes on the water encountered are as follows:—

(*a*) *Level of Water*

"A rise of the water level inside the lining was noted when a depth of 895-898 ft. was reached and in 28 hours water rose from 154 below O.D. to 39 above O.D. and was continuing to rise at a rate of 2 ft. in $1\frac{3}{4}$ hours.

At a depth of 907-909 ft., water having incidentally been lowered by shelling out to 62 below O.D. a rapid rise of 171 ft. occurred in 3 hours, and in $6\frac{3}{4}$ hours it had risen 230 ft., to 27′ 6″ below the surface. The water was allowed to flow into the Chalk at this level to avoid possible overflowing and flooding. A subsequent measurement of the pressure of the water gave a value of 53 ft. above the surface, that is, 249 above O.D.

The quantity of water which overflowed at the surface was 6 gallons per minute.

(*b*) *Quality of Water*

The water overflowing had a slightly earthy taste but was generally palatable, while having a total hardness of only 8.8 parts per 100,000 of $CaCO_3$. A slight trace of manganese was present.

By blowing compressed air down the bore tube a flow was induced in the annular space between the $12\frac{1}{2}$″ internal diameter

lining and the 13″ outside diameter lining and a discharge of 30 gallons per minute was obtained which fell to 13.3 gallons per minute after 72 hours. The subsequent overflow at the surface (without air lifting) was 7 gallons per minute.

The water, subsequent to the inducement of greater flow by air lifting, was found to be saline and continued so. Analyses of both types of water are appended.

The bore is to be stopped up at the base of the Chalk and the lining case recovered."

(*c*) *Analysis of Water*

In parts per 100,000. Analyses by the Chemical and Bacteriological Laboratory of the Colne Valley Water Company.

	(A) Water Initially Tapped	(B) Water After Air Lifting
Appearance	Turbid. Some sand, all settling completely in 2 hours.	Clear. Becoming turbid and yellow on standing. Ferruginous deposit with organic debris and sand.
Colour	45 mm.*	Very turbid
Odour	Normal	Normal
Reaction *p*H	7.5	7.9
Total Solids dried at 180°C	48.50	448.10
Chlorides (Cl)	12.90	251.40
Nitrates (N)	0.023	0.24
Nitrites	v. slight trace	v. slight trace
Hardness $CaCO_3$ per 100,000 — Total ...	8.8	17.6
Hardness $CaCO_3$ per 100,000 — Permnt. ...	2.3	11.2
Hardness $CaCO_3$ per 100,000 — Tempry. ...	6.5	6.4
Iron	.001	0.035
Copper, Zinc, Lead ...	Absent	Absent
Manganese	v. slight trace	v. slight trace
Free Ammonia	0.3425	0.1371
Albuminoid Ammonia ...	0.0315	0.0025
Oxygen absorbed— 3 hrs.—37°C	0.406	0.069
Free Chlorine	Absent	Absent
Free CO_2	0.7	0.4
Probable Combinations		
$CaCO_3$	9.10	18.73
$MgCO_3$	0.73	2.22
$MgSO_4$	—	5.89
Na_2CO_3	5.92	—
Na_2SO_4	10.98	2.81
NaCl	21.26	414.31
$NaNO_3$	0.14	1.45
SiO_2	0.70	0.60
Error etc.	0.33	2.09
Total Solids Dried at 180°C	48.50	448.10

* Burgess Scale.

The fact that water rises from the Devonian rocks at Bushey, from a depth of about 900 ft. to above surface level, brings forward the interesting problem of the location of the ' head ' of water sufficient to furnish the necessary pressure. On examining records of other bores to Palaeozoic rocks in the London area, it is found that where water has been struck it is usually under a head sufficient to raise a column to above surface level. For example, at Stonebridge Park, Willesden, where Gault overlies Palaeozoic rock, water rising from 968 ft. overflowed at the surface, and again at Richmond water from 1,387 ft. down rose, on a gauge, 126 ft. above the surface.

Palaeozoic rocks have been found in some dozen bores in the London area and in others in the surrounding districts; from the evidence thus provided it is concluded that Palaeozoic strata lie at an average depth of about 1,000 ft. below sea level. Nowhere nearer than their outcrop at the northern end of the Bristol Coalfield and in Wales do they rise to a height sufficient to provide, by themselves, the head of water required. Further, between London and Wales several strong anticlinal folds probably occur, as that shown by such boreholes as Calvert, where Cambrian rocks are 443 ft. below the surface; these would interrupt any flow from Wales.

Consequently the location of the ' head ' must be sought nearer London.

The degree of salinity of the water constitutes a further point bearing on this question. When records of analyses have been preserved, it is found that water from Palaeozoic rocks has proved to be highly saline. At Stonebridge Park the total solids in the water constituted about 1,400 parts per 100,000 : water from the Streatham bore was ' rather brackish ', and, as has been noted above, at Bushey 448 parts of ' solids ' (chiefly sodium chloride) per 100,000 were shown to be present at the final analysis.

It is unknown whence the saline matter comes. It may be derived by contamination from the basal beds of the Gault, since many Lower Greensand waters contain a fair percentage of salt, for instance at Winkfield, water contains 62 parts of saline matter per 100,000, and this figure appears to be an average, the most saline types containing about 90 parts per 100,000, such as a water from Histon, Cambs. Yet such analyses as are available show that nowhere does the degree of salinity in Lower Greensand water approach anywhere near that of water from the Palaeozoic rocks.

A second explanation is that water from the Palaeozoic rocks is a ' fossil ' water, *i.e.* one which was sealed in the rocks prior to the deposition of the next overlying impervious bed, this being the Gault in most of the cases in South-Eastern England. Such water may be expected to have dissolved large quantities of mineral matter during its long sojourn below the ground.

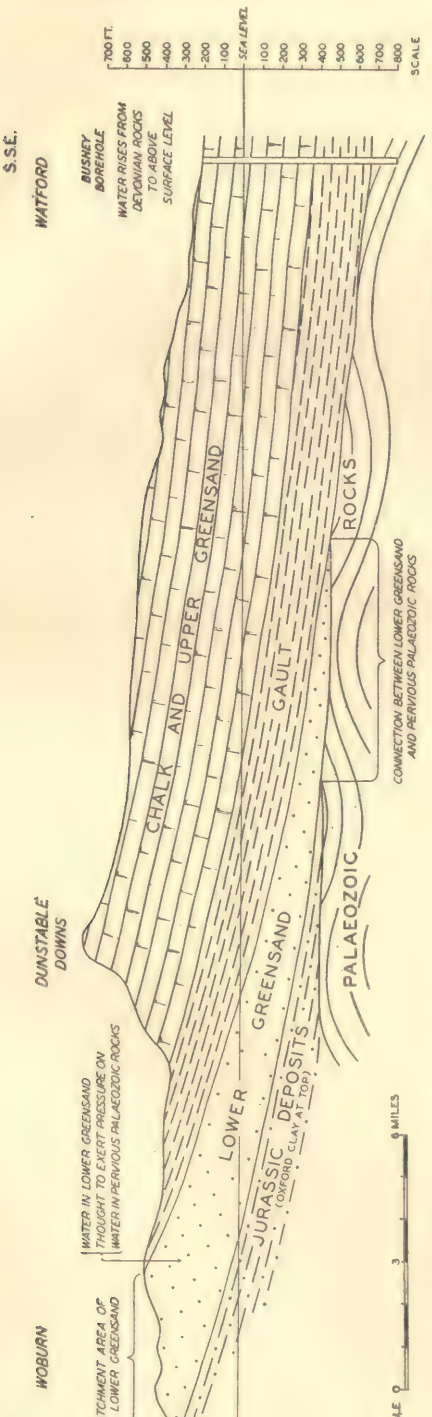

FIG. 1—*Diagrammatic Section to illustrate the probable circulation of water rising from Palaeozoic (Devonian) rocks to above surface level at Bushey, Herts.*

But at Bushey the water first struck below the Gault was soft and of good quality (Analysis A) and it is probable that it had travelled from the surface comparatively recently. It is thought that in effect two waters were encountered. At some locality to the north-west, the precise position of which cannot be estimated with reliability, but which is not far away from the borehole, Lower Greensand probably overlies pervious Devonian sandstone of the type encountered in the Bushey borehole and water may percolate through both series of beds from the Lower Greensand outcrop around Leighton Buzzard and Woburn. On this hypothesis, water in the Lower Greensand exerts pressure on water in the Devonian rocks; this conception is illustrated in Fig. 1. Pumping operations appear to have exhausted the supply of good water taken in from the Lower Greensand more rapidly than it could be replenished, and a saline, fossil water was then extracted. (Analysis B.) This explanation appears to account for the known facts in this instance.

A similar hypothesis may possibly apply to the other sites in the South-East of England where water from deep-seated Palaeozoic rocks overflows at the surface, *i.e.* that pervious beds of Mesozoic age overlie pervious Palaeozoic rocks, and so furnish the necessary head of water.

VI.—*MIXOPTERUS DOLICHOSCHELUS* (LAURIE MS.), A DOWNTONIAN EURYPTERID FROM SCOTLAND

BY

Dr. LEIF STÖRMER

OF THE UNIVERSITY OF OSLO

Plate IV, and Text-figure 1.

INTRODUCTION

IN their classical work on the Silurian rocks of Scotland, Peach and Horne (1899, p. 578) mention the occurrence of *Eurypterus dolichoschelus* (Laurie) in Downtonian beds of Dippal Burn and near Seggholm in Slot Burn, Lanarkshire.

Since well-preserved eurypterids occur in Downtonian sandstones of the Oslo area in Norway, the author was especially desirous of finding a description of the above-mentioned species from the Downtonian of Scotland. It appears that *Eurypterus dolichoschelus* is a manuscript name.

I wish to express my sincere thanks to Dr. R. Campbell, Dr. J. Pringle and Dr. C. J. Stubblefield for assisting me in gathering information about this species. Through the kindness of Dr. Pringle I have been privileged to borrow a specimen (figured on the plate) from the Geological Survey Collection in Edinburgh.

I am also indebted to Sir John Flett, the Director of the Geological Survey of Great Britain, for giving me the opportunity of publishing the present account.

In the middle of the last century the British authors Huxley, Salter and H. Woodward published their valuable monographs on the peculiar, often gigantic, merostomes from the Palaeozoic rocks of Great Britain. Besides the striking *Pterygotus* forms, some other eurypterid species were described which showed a remarkable scorpion-like shape of the body. The large anterior walking legs and particularly the narrow post-abdomen terminating in a strong spine, express the scorpionid characters. Thanks to the extensive studies by Clarke and Ruedemann (1912) on the American eurypterids, it became possible to throw more light on this interesting group of the Eurypterida. The two American authors included several British and American species in Grote and Pitt's genus *Eusarcus*. The name *Eusarcus* is unfortunately preoccupied so it has been necessary to replace it by the name *Carcinosoma*, Claypole (see Störmer 1934, p. 104). The American Ordovician genera *Megalograptus* and *Echinognathus*, of which the latter attained a length of 1 metre, are related to the genus *Carcinosoma*.

More recently Ruedemann (1921) has separated from *Carcinosoma* a new genus which he calls *Mixopterus*. The species

belonging to this genus are chiefly distinguished by the strong development of the second pair of walking legs which have numerous long spines not very different from those seen in *Stylonurus* (*Ctenopterus*). Specimens from the Norwegian Downtonian have furnished valuable contributions to our knowledge of the genus *Mixopterus* which differs from *Carcinosoma* in several characters. The eurypterid described below, confirms in an interesting way the relationship between *Carcinosoma* and *Mixopterus*. *Mixopterus dolichoschelus* exhibits typical *Mixopterus* characteristics in the strong development of the second pair of walking legs. These legs are more than twice as long as the posterior ones. The rather narrow abdomen also indicates the genus.

The *Carcinosoma* characteristics are suggested in the structure of the swimming leg and in the lack of distinct dorsal furrows.

Typical species of the genus *Carcinosoma*, such as *C. scorpioides* (H. Woodw.) Woodward, 1872, pl. xxix, and *C. scorpionis* (Grote & Pitt), Clarke and Ruedemann, 1912, pls. xxvii-xxxiv, have the three posterior walking legs well-developed and the second pair or most anterior of the three is not much larger than the posterior ones. Each joint of the appendages has only one pair of spines. The swimming legs have a long eighth joint. The broad, rounded prosoma has no dorsal furrows.

Laurie, 1899, p. 585, pl. iv, figs. 23-25, pl. v, fig. 26, has described an interesting species *Carcinosoma scoticum* from the Wenlock of Scotland. This form, although being a typical *Carcinosoma* in regard to the shape of prosoma and the equal size of the walking legs, also shows, in the presence of the numerous spines of the walking legs and the rather narrow abdomen, a connexion with the genus *Mixopterus*. *M. dolichoschelus* contributes, especially in the development of the swimming leg, to fill in the gap between the two genera. Text-figure 1 illustrates the relation between the distal joints in species of the genera *Carcinosoma* and *Mixopterus*. In the typical species of the first genus (a) the eighth joint is longer than the seventh. In *Carcinosoma scoticum* (b) the joints have about the same length. In *Mixopterus kiaeri* (d) the eighth joint is considerably shorter than the seventh. *M. dolichoschelus* (c), and perhaps also *M. multispinosus*, forms a distinct transition stage. As indicated above, the other morphological characters also suggest a transition between the genera *Carcinosoma* and *Mixopterus*, and the combination of characters therefore is of considerable phylogenetic interest.

The Scottish Downtonian species *Mixopterus dolichoschelus* (Laurie MS.), probably stood near the common ancestor of *Carcinosoma* and *Mixopterus*.

Description and Remarks

EURYPTERIDA Burmeister

Family Carcinosomidae Störmer 1934

Genus *Mixopterus* Ruedemann 1921

Mixopterus dolichoschelus (Laurie MS.)

Plate IV and text-fig. 1

Eurypterus dolichoschelus (Laurie). Peach and Horne 1899, p. 578.

Diagnosis.—Swimming leg with short seventh and long eighth joint. Mesosoma short with only traces of dorsal furrows. First segment of metasoma apparently without acute angles.

Holotype.—No. T. 3357 of the Geological Survey Collection in Edinburgh, Scotland.

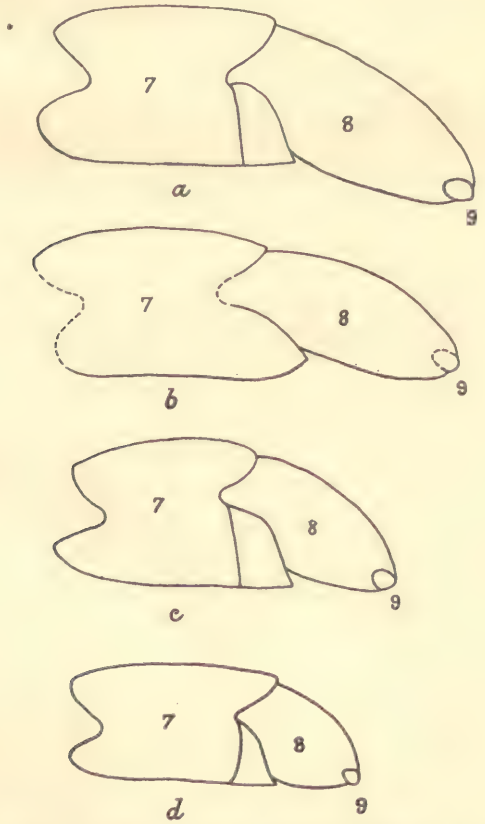

Fig. 1—*Outline drawings of the distal part of the swimming leg of* **a**, Carcinosoma scorpionis (*Grote and Pitt*); **b**, C. scoticum (*Laurie*); **c**, Mixopterus dolichoschelus (*Laurie MS.*), **d**, M. kiaeri *Störmer*. *7, 8, 9, indicate the three distal joints of the appendages* (**a** *and* **b** *modified after Clarke and Ruedemann* 1912 *and Laurie* 1899).

State of Preservation.—The strongly compressed specimen is not very well preserved. The anterior and central portions especially do not show many structural details. By reason of the compression both the dorsal and ventral surface appear in part as superposed adpressed surfaces.

General description.— The body has a scorpion-like appearance. The outline of prosoma is not marked.

Of the six prosomal appendages the outlines of the posterior five pairs are indicated. The first walking leg (second pair of appendages, II) is partly preserved. The rather broad proximal portion suggests a fairly strong appendage of the type found in *Carcinosoma scoticum* (Laurie). Several transverse joint-lines are indicated. No traces of a clasping (?) organ are found. The second walking legs, III, are developed as two long and powerful limbs; these are more than twice as long as the posterior ones. The long appendages narrow gradually towards the distal curved, striated, flat spine, the median concave margin of the limb is furnished with similar long and short spines, of which only a few are preserved. The joint-lines of the leg cannot be distinguished.

The third walking leg, IV, is short and curved. It is possible to separate seven different joints of which the last forms the distal claw. The eighth joints correspond closely to those of *Mixopterus kiaeri*, Störmer 1934. Some of the short flat spines are preserved in the distal part.

The last walking leg, V, is shorter than the preceding. Seven joints are visible. The fourth walking leg is not turned over on the side in the same degree as the second and third. In the walking legs a spineless seventh segment is indicated, a structure which is characteristic of the genus.

The swimming leg, VI, is well preserved in the distal part. The flat ' palette ', formed by the seventh and eighth joints is strongly developed. The rather short seventh joint has two deep notches representing the sockets of the joints. A post-lateral suture shows a subtriangular lobe. Another suture shows that the lobe is more narrow on the dorsal side. The ovoid, eighth joint is shorter than the seventh. A small ninth segment is present.

The mesosoma is rather broad. Only faint traces of dorsal furrows are present. The first tergite is not preserved. The limits between the tergites are transverse in the median part and curved in an anterior direction, laterally. The length-width ratio of the tergites is about 1 : 7.

The genital appendage (*ga* on Plate IV) is indicated extending posteriorly towards the middle of the fourth segment of mesosoma. The shape with the non-divergent distal spines resembles closely the appendage of ' type A ' seen in *Mixopterus* and *Carcinosoma* (see Störmer, 1934, p. 46).

The anterior segment of the metasoma has apparently no acute post-lateral angles. The narrow posterior part of the metasoma

consists of five segments increasing in length and decreasing in width towards the telson which however is not preserved.

Ornamentation.—Scattered on the opisthosoma, are numerous minute pits, or circular depressions which evidently correspond to small tubercles on the dorsal surface. The part of opisthosoma preserved probably represents the inside of the test. On the walking legs, one or two longitudinal rows of pits are indicated. An ornamentation consisting of scattered, minute tubercles is characteristic of the family Carcinosomidae.

Dimensions.—Length, median line without telson, 165 mm. Probable length including the anterior stretched legs and the telson, 275 mm. Length of second walking leg (III) without coxa and distal spine, 70 mm.; the third and fourth legs (IV, V): 31 mm., 23 mm. respectively. In the swimming leg the lengths of the seventh and eighth + ninth joints are 21 mm. and 18 mm., respectively. Prosoma has a length of about 39 mm., and the width is 51 mm. The third tergite has a length of 8 mm. and width of 57 mm. The length of metasoma without telson is 98 mm.

Occurrence.—According to the label, the specimen described here was found in Downtonian beds of Seggholm, Muirkirk, Lanarkshire. The locality is probably the second one mentioned by Peach and Horne, 1899, p. 578. The rich vertebrate fauna of these beds consists of species of *Lanarkia, Birkenia, Lasanius, Thelodus* and *Ateleaspis*. The fauna also contains, among other forms, *Dictyocaris* and *Stylonurus ornatus*.

Relationship.—As already pointed out, the species differs considerably from other described species of the genus *Mixopterus*. *M. multispinosus* (Clarke and Ruedemann), Ruedemann 1921, resembles the present form in the several characters, but deviates in the shape of mesosoma and the length of the segments of metasoma. The American Silurian species is not known in detail. The remnants of the swimming leg (*op. cit.*, pl. i, fig. 3 and pl. iii, fig. 6) show an interesting resemblance to the British species. The seventh joint has nearly the same proportions.

The well-known Norwegian *M. kiaeri* Störmer 1934, from the Downtonian (?) beds of the Oslo area, differs considerably in the structure of the second and sixth pair of appendages, the slender mesosoma and the first segment of metasoma. The Baltic *M. simonsoni* Schmidt 1904, from the *Eurypterus fischeri* beds of Oesel, is probably closely related to the Norwegian species.

The British and Norwegian species occur in beds of apparently the same age. Kiaer, 1924, p. 18, has demonstrated the striking resemblance in the general characteristics of the faunas. The Norwegian Rudstangen fauna contains Anaspida, Cephalaspidae (*Aceraspis* related to *Ateleaspis*), Thelodonti (*Thelodus*), Eurypterida (*Hughmilleria, Stylonurus, Pterygotus, Mixopterus*) and in abundance, the supposed crustacean *Dictyocaris*. Only the species of *Dictyocaris* seems to be identical in the otherwise comparable faunas.

The Baltic *Eurypterus* fauna, although being older than the Rudstangen fauna of Norway, might perhaps be equivalent to the base of the Downtonian of Great Britain (see Stamp, 1923, p. 405 and Straw, 1933, p. 139).

The three European species of the genus *Mixopterus*, *M. simsoni*, *M. kiaeri* and *M. dolichoschelus* seem to occur in the lower part of the Downtonian, or in the transition beds between the Ludlovian and Downtonian Series.

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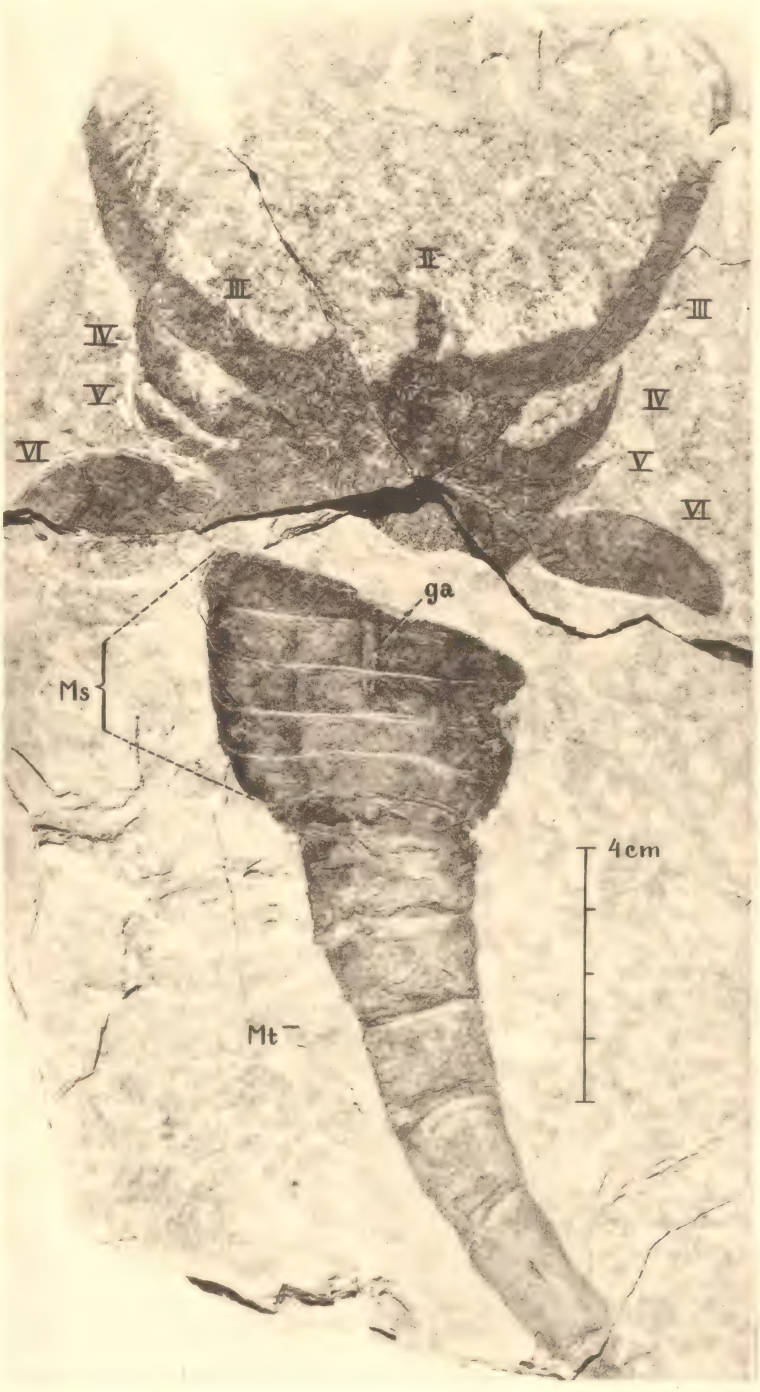

MIXOPTERUS DOLICHOSCHELUS (Laurie MS.)

Description of Plate IV

Mixopterus dolichoschelus (Laurie MS.). Downtonian. Seggholm, Muirkirk, Lanarkshire. Holotype specimen numbered T.3357 in the Geological Survey Collection (Royal Scottish Museum), Edinburgh.

Fairly complete specimen. The size is indicated by the scale. II-VI= the five posterior of the six prosomal appendages, of which II-V are walking legs, and VI, the swimming legs. *Ms*=mesosoma, *Mt*=metasoma, *ga*= genital appendage. The specimen has been photographed when emersed in alcohol and the photograph slightly retouched.

VII.—THE *CYRTINA SEPTOSA* BAND IN THE LOWER CARBONIFEROUS SUCCESSION OF NORTH DERBYSHIRE

BY

F. WOLVERSON COPE, M.Sc.

Text-figure 1.

INTRODUCTION

THE mapping of structures in the Lower Carboniferous rocks is rendered more easily possible by the presence of bands or layers of rock in which fossils are more or less abundant. Frequently, certain assemblages of fossils which can be recognized over considerable distances characterize these bands. In this country, Prof. Garwood was the first to map fossil-bands when he studied the Carboniferous succession in Cumberland and Westmorland[1]. One of the most easily recognized, and at the same time most widespread of fossil-bands in that region (North-West Province) is that which is characterized by the abundance of '*Chonetes* aff. *comoides* and *Cyrtina septosa*'. It occurs near the summit of the D_1 subzone and has been traced for many miles in the D_1 limestones of Cumberland, Westmorland and more recently of Yorkshire. Up to the present the occurrence of this band has been thought to be restricted to the North-West Province. Its occurrence in the Midland Province of Derbyshire however is the subject of this paper. At the same time this is a strong thread in the correlation of the Lower Carboniferous of Derbyshire with that of the North-West Province; other threads exist but their description is outside the scope of the present communication.

THE LOWER CARBONIFEROUS SUCCESSION

The succession of Lower Carboniferous rocks in North Derbyshire is briefly summarized here in order to define the position of the *Cyrtina septosa* band in its relation to other horizons. Only the central area of limestones of Great Scar facies is considered, and no attempt has been made as yet to trace the *Cyrtina septosa* band from this region into the reef-limestones which fringe the limestone massif although the band has been noticed by the writer at a number of localities in the knoll-reef area.

The type-section is taken along the line of the London Midland & Scottish Railway from Buxton to Great Longstone through the valley of the River Wye. The base of the Carboniferous is

[1] Garwood, E. J., 'The Lower Carboniferous Succession in the North-West of England.' *Quart. Journ. Geol. Soc.*, vol. lxviii, 1912, pp. 449-586.

nowhere exposed but the writer has pointed out his reasons for believing that the base lies not far below the lowest beds seen near Topley Pike, 3 miles to the east of Buxton[1]. Evidence as to the nature of the Basement Beds has already been discussed.[2] Above these beds, about 1,450 feet of strata are to be referred to the Lower Carboniferous[3]. The lowermost 300 feet consist of dark-coloured and mainly thinly-bedded dolomitized limestones and calcite mudstones (Daviesiella Beds), followed by about 300 feet of thickly-bedded light-coloured limestones (Chee Tor Beds). These are succeeded by two lava flows which are separated by 150 feet of limestones (Miller's Dale Beds). Succeeding the upper lava flow are thinly-bedded dark-coloured limestones with chert which towards the top become interbedded with shales. In connexion with the *Cyrtina septosa* band, only that part of the succession below the lower lava flow is of importance. In Fig. 1 is set out the arrangement of these beds together with the extent of the faunal subzones as determined by an extensive investigation of the faunas.

The *Cyrtina septosa* Band

Position in the Sequence.—As shown in the figure, the band occurs in the Chee Tor Beds about 25 feet below the base of the lower lava flow. It is therefore about 150 feet below the summit of the D_1 subzone (excluding the thickness of the lava flow which has a maximum value of about 84 feet[4]). The Chee Tor Beds form a monotonous series of thickly bedded light-coloured fine-grained limestones which are poorly fossiliferous.

Lithology.—The limestone composing the band is invariably light grey in colour and fine-grained in texture with occasional fragments of crinoid ossicles; it varies in thickness from 1 to about 10 feet. No change in lithology above the band is to be observed.

Palaeontology.—The following is a list of the fossils which have been obtained from the *Cyrtina septosa* band of North Derbyshire:—

Cyrtina septosa (Phill.).
Daviesiella sp. [aff. D. *comoides* (J. Sow.)].
Athyris sp.
Productus hemisphaericus J. Sow.
Palaeosmilia murchisoni (Ed. & H.).
Chætetes depressus (Flem.).
Carcinophyllum sp. [cf. *Carcinophyllum* θ Vaughan]
Syringopora spp.

[1] Cope, F. W., 'A Tholeiite Dyke near Buxton, Derbyshire.' *Geol. Mag.*, vol. lxx, 1933, p. 422.
[2] Cope, F. W., *ibid.*, pp. 421-22.
[3] Cope, F. W., 'The Lower Carboniferous Succession in the Wye Valley Region of North Derbyshire.' *Journ. Manchester Geol. Assoc.*, vol. i, pt. 3, 1933, pp. 125-145.
[4] Arnold-Bemrose, H. H., 'The Toadstones of Derbyshire; their Field-Relations and Petrography.' *Quart. Journ. Geol. Soc.*, vol. lxiii, 1907, p. 250.

The *Daviesiella sp.* [aff. *D. comoides*] is usually common and is sometimes present almost to the exclusion of other members of the fauna. The brachiopod in question is identical with that described as *Chonetes* aff. *comoides* from the *Cyrtina septosa* band of the North-West Province by Prof. Garwood.

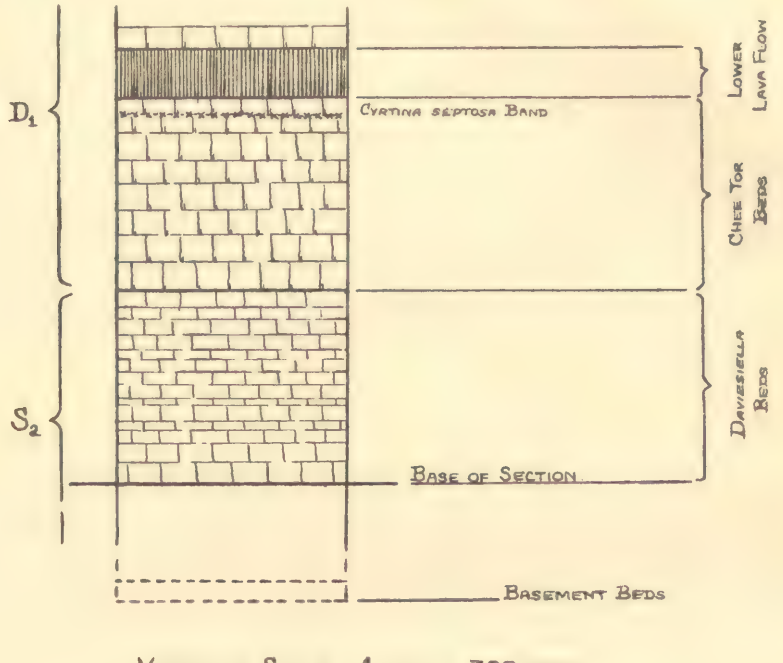

Fig. 1—*Succession below the Lower Lava Flow in the Type-Section of Lower Carboniferous Rocks in North Derbyshire.*

Localities.—In the type-section, the band is exposed in both limbs of the anticline; in the western limb, it is seen in the railway-cutting about 100 yards east of Ashwood Dale Tunnel. It is there about 4 feet in thickness and lies about 20 feet below the lower lava flow which crops out in the embankment above. In the eastern limb, it is well exposed in the vertical cutting on the north side of the railway line about 120 yards west of Chee Tor Tunnel No. 2 (4½ miles to the east of Buxton). There, the beds are dipping towards the north-east at an angle of about 5° and the *Cyrtina septosa* band is about 4 feet thick. The band is well seen also at Buxton Bridge some 2½ miles to the north-east of Buxton. A few yards to the east of the bridge over the railway is a narrow road cutting[1] giving access to a limestone quarry, and the band showing its maximum thickness is exposed at the south end of this cutting. Other good exposures occur in Monk's Dale to the north of Miller's Dale village.

[1] *Geol. Mag.*, vol. lxx, 1933, p. 414.

Comparison with the North-West Province

In the North-West Province, the *Cyrtina septosa* band occurs 80 to 100 feet below the summit of the D_1 subzone, the limestones of which are pure and poorly fossiliferous. In North Derbyshire, the band lies about 150 feet below the summit of the D_1 subzone, and there too the beds of the subzone are very pure limestones yielding few fossils. In both areas, beds with *Daviesiella llangollensis* (Dav.) occur some distance below the band. The fauna of the band in North Derbyshire is practically identical with that of the band in the North-West Province.

The *Cyrtina septosa* band is therefore shown to be of some importance in the correlation of the Lower Carboniferous deposits of the two areas.

EX BIBL. UNIV. EDINBURGEN.

VIII.—NOTES ON THE TYPES AND FIGURED SPECIMENS ACQUIRED FROM THE LATE S. S. BUCKMAN BY THE GEOLOGICAL SURVEY OF GREAT BRITAIN

BY

C. J. Stubblefield, Ph.D., A.R.C.Sc.

BETWEEN the years 1886 and 1929, the Geological Survey and Museum acquired portions of the large collection of Mesozoic fossils made by the late S. S. Buckman including nearly 700 types and figured specimens. A stratigraphically arranged manuscript catalogue of these types and figured specimens has been prepared but it appears to be too large to form an economical publication. Some of the specimens acquired in earlier years from S. S. Buckman subsequently became figured and described by him and are marked in his publications as being in the Geological Survey Collections. A few specimens have been figured by other workers, for example, *Stichoporella stutterdi* (W. Carruthers) registered in the Geol. Surv. Mus. as No. 2260[1], and three ammonites, *Aposphinctoceras variabile* Neaverson, *Paravirgatites kimmeridgensis* Neaverson and *Sphinctoceras distans* Neaverson[2].

Since specimens falling into either of these categories are already stated to be in the Geological Survey Collection, no further cognizance is taken of them in these notes which are designed to be of use to palaeontologists desirous of locating the present whereabouts of the specimens stated by Buckman to be in his own collection at the time he figured or described them.

The main number of the remaining 600 specimens are brachiopods and ammonites and will be treated under those headings, but before dealing with those groups, it might be remarked that the Geological Survey's purchases included a slab showing thirty shells of the Corallian lamellibranch, *Trigonia clavellata* J. Sowerby from Osmington Mills, Dorset, figured by J. Buckman in a paper, ' On some Slabs of *Trigonia clavellata* from Osmington Mills, Dorset,' *Proc. Dorset Nat. Hist. and Antiq. F.C.*, vol. ii, 1878, plate facing p. 19 This slab is now registered as No. 47602.

In the notes which follow, in square brackets are given the numbers referring to the individual specimens in the Geological Survey registers.

[1] Edwards, W. N., ' On the Algal Nature of *Aroides stutterdi* Carruthers,' *Ann. Mag. Nat. Hist.*, Ser. 10, vol. i., 1928, pl. iii, fig. 5, p. 79.

[2] Neaverson, E., ' Ammonites from the Upper Kimmeridge Clay,' *Papers from the Geological Department of the University of Liverpool*, 1925, pl. ii, figs. 5a, 5b, p. 29 ; pl. iv, fig. 4, p. 33 and pl. iv, fig. 3, p. 23 respectively.

I. Type and Figured Brachiopods

1. All specimens figured by S. S. Buckman in his paper ' Homoeomorphy among Jurassic Brachiopoda ', *Proc. Cotteswold Nat. Field Club*, vol. xiii, 1901, pls. xii and xiii except *Zeilleria emarginata* (J. de C. Sowerby) pl. xiii, figs. 5a, b, c. [Nos. 31920, 31995 and 47203-47216].
2. All specimens figured by S. S. Buckman, from the J. Buckman or his own collection, in the paper ' Some Species of the Genus *Cincta* ', *Ibid.*, vol. xvi, 1907, pls. v and vi [47578-47582]; also various unfigured paratypes [47583-47587, 47589, 47592-3].
3. All (brachiopod) specimens figured by S. S. Buckman from his own collection, in ' Certain Jurassic (' Inferior Oolite ') Species of Ammonites and Brachiopoda,' *Quart. Journ. Geol. Soc.*, vol. lxvi, 1910, pl. xii only and not including figs. 7 and 8. [31932, 31968, 47217-47223].
4. All British specimens figured by S. S. Buckman from his own collection, J. W. Tutcher's and that of the Imperial College of Science[1] in ' The Brachiopoda of the Namyau Beds, Northern Shan States, Burma.' *Palaeontologia Indica*, New Series, vol. iii, Mem. No. 2, 1917 [31864-31999, 47597, 51228, 51281-51331].

II. Type and Figured Ammonites

1. The publication ' Type Ammonites '

This work by S. S. Buckman appeared in seven volumes published at intervals between the years 1909 and 1930. The first two volumes were entitled ' Yorkshire Type Ammonites.' The last two parts to appear were published posthumously by order of the author's executors and they include an editorial note, chronological and other tables and an index by Professor A. Morley Davies. In the case of all the specimens figured in these seven volumes their location in various private collections is specified either on the appropriate plate or in the text. Among other collections that of the Geological Survey and Museum is variously referred to as ' Geol. Surv. Eng. Coll.,' ' Geol. Survey,' ' Geol. Survey Coll.,' ' M. P. G.,' ' Mus. Pract. Geol.,' ' Mus. Pract. G. Coll.,' ' Jermyn St. Mus.,' etc.

Many of the specimens figured were at one time in the author's private collection and are designated on the plates or in the text ' S. Buckman Coll.,' ' S. B. Coll.,' ' S. B. ex J. B. Coll.,' ' S. B. ex Darrell Coll.,' etc. The great majority of these are now in the possession of the Geological Survey and Museum. Excluding reference to the figured specimens formerly in the S. Buckman Collection which are stated on the plates to have become subsequently lodged elsewhere, of those figured in each volume the number that are now in the collection of the Geological Survey and Museum is set forth in the following statement.

[1] Presented by the college authorities *per* Prof. A. Morley Davies, 1924.

'Yorkshire Type Ammonites,' vol. I.—The Geological Survey has no figured S. S. Buckman Collection specimens.

'Yorkshire Type Ammonites,' vol. II.—Of the eight S. S. Buckman Collection figured specimens then unallocated to any other collections the G. S. & M. now has all but one, namely *Tiltoniceras costatum,* S. Buckman, pl. xcvii, figs. 1-2. The register numbers of the seven specimens are 47090-47096. (The two unallocated Clarkson Collection specimens figured as pls. lxxvii, and lxxx are also now in the G. S. & M. Collection, numbered 26403, 26408 respectively).

'Type Ammonites,' vol. III.—Of the 68 S. S. Buckman Collection figured specimens then unallocated to any other collections the G. S. & M. now has all but one, namely *Labyrinthoceras perexpansum* S. Buckman, pl. cxxxivA, cxxxivB. [32000-32065, 47105].

'Type Ammonites,' vol. IV.—All 97 of the S. S. Buckman Collection figured specimens then unallocated to any other collection are now in the G. S. & M. collection including *Goliathiceras microtypa* S. Buckman, pl. ccclxxx. [47106-47202].

'Type Ammonites,' vol. V.—All 92 of the S. S. Buckman Collection figured specimens then unallocated to any other collection are now in the G. S. & M. collection. [37288-37328, 47524-47574].

'Type Ammonites,' vol. VI.—All 97 of the S. S. Buckman Collection figured specimens unallocated to any other collection are now in the G. S. & M. collection [47759-47783, 47821-47851, 49269-49309].

'Type Ammonites,' vol. VII.—Of the 50 S. S. Buckman Collection figured specimens unallocated to any other collection, the G. S. & M. has all but one, namely *Zugodactylites rotundiventer* S. Buckman, pl. dccxliii. The register numbers of the 49 specimens are 49310-49358.

2. Publications[1] of Buckman's appearing before 'Type Ammonites'

The Geological Survey and Museum collections contain various early S. S. Buckman acquisitions which were not refigured by him in his publication 'Type Ammonites'—these specimens are here set out under the major stratigraphical horizons in which they were found. The names given are those under which the descriptions were published, and these are arranged alphabetically.

[1] By the courtesy of Dr. W. E. Schevill of the Museum of Comparative Zoology at Harvard, Cambridge, Massachusetts, the Director of the Geological Survey has recently been supplied with a list of the 92 Ammonite types, referred to or figured by S. S. Buckman in the 'Monograph of the Ammonites of the "Inferior Oolite" Series,' Supplement, *Palaeont Soc.* (1898-1905), which were acquired by that museum in 1906 and are numbered MCZ. 2468-2559. This list is available for inspection at the Geological Survey Museum.

To conserve space, the following abbreviations are adopted :— *M.* = ' Monograph of the Ammonites of the " Inferior Oolite " Series,' *Palaeont. Soc.*, 1889-1894; S. = ' Supplement ' to that monograph, *Palaeont. Soc.*, 1898-1907; [Cast of figured H] = Cast of figured Holotype; [H] = Holotype; [P] = Paratype; [P. fide S. S. B.] = Paratype according to S. S. Buckman's MS. label; [P.* fide S. S. B.] = Paratype according to S. S. Buckman's MS. label but probably incorrectly termed Paratype since the specimen was not mentioned when the name was first proposed; [S] = Syntype.

A. *Inferior Oolite Ammonites*

Ancolioceras cariniferum S. Buckman 1899 [Cast of figured H]; Mapperton, near Beaminster, Dorset. Figured *S.*, 1899, pl. XI, figs. 7, 9, p. xlvii. [27607].

Asthenoceras nannodes (S. Buckman 1890), [S]; Stoford, Somerset. Figured *M.*, 1890, pl. XXXIII, figs. 13, 14, p. 213 as *Grammoceras nannodes* S. Buckman; *S.*, 1899, p. xlix. [6726].

Brasilina crinalis S. Buckman 1904 [P. fide S. S. B.]; Sherborne, Dorset. Referred to in *S.*, 1904, p. lxxxiv. [12581].

Braunsella? rotabilis S. Buckman 1904 [Cast of figured H]; Bradford Abbas, Dorset. Figured *S.*, 1904, pl. XVII, figs. 7, 9, p. cii. [27629].

Braunsina? anguilifera S. Buckman 1902 [P.* fide S. S. B.]; Beaminster, Dorset. Referred to in *S.*, 1904, p. ci. [12531].

B? anguilifera S. Buckman 1902 [P.* fide S. S. B.]; Bradford Abbas, Dorset. Referred to in *S.*, 1904, p. ci. [12532].

Braunsina elegantula S. Buckman 1904 [P. fide S. S. B.]; Bradford Abbas, Dorset. Referred to in *S.*, 1904, p. c. [12530].

Crickia reflua S. Buckman 1899 [P. fide S .S. B.]; Chideock Quarry Hill, near Bridport, Dorset. Referred to in *S.*, 1904, p. lxxiv; also in *Quart. Journ. Geol. Soc.*, vol. lxvi, 1910, p. 63. [12553].

Darellella recticostata S. Buckman 1904 [Cast of figured H]; Bradford Abbas, Dorset. Figured *S.*, 1904, pl. XVII, figs. 10, 12, 12a, p. cvii. [27624].

Darellia concinna S. Buckman 1904 [P. fide S. S. B.]; Dundry, Somerset. Referred to in *S.*, 1904, p. cxiv. [12549].

Darellia toxeres S. Buckman 1904 [P. fide S. S. B.]; Stoke Knap, near Beaminster, Dorset. Referred to in *S.*, 1904, pp. cxiii-cxiv. [12548].

Darellina dorsetensis S. Buckman 1904 [P. fide S. S. B.]; Stoke Knap, near Beaminster, Dorset. Referred to in *S.*, 1904, p. cvi; see also *Quart. Journ. Geol. Soc.*, vol. lxvi, 1910, p. 77. [12540].

Deltoceras[1] *subsectum* S. Buckman 1902 [P.* fide S. S. B.];

[1] The generic name was spelt as *Deltoceras* in S. S. Buckman ' Emendations of Ammonite Nomenclature,' Cheltenham, 1902, p. 3, but an attempt to change this to *Deltotoceras* was made by Buckman in *S.*, 1904 *loc. cit.*

Wistley Hill, near Cheltenham, Glos. Referred to in *S.*, 1904, p. cxxi. [24751]. See also *Quart. Journ. Geol. Soc.*, vol. li, 1895, p. 414, where the specimen is referred to as *Hyperlioceras* cf. *discoideum* (Quenstedt).

Depaoceras hamatum S. Buckman 1904 [P. fide S. S. B.]; Halfway House, Sherborne, Dorset. Referred to in *S.*, 1904, p. lxxix. [12554].

Dissoroceras tabulatum S. Buckman 1902 [P. fide S. S. B.]; Bradford Abbas, Dorset. Referred to in *S.*, 1904, p. cxv. [12573].

Dorsetensia liostraca S. Buckman 1892, forma γ S. Buckman 1892 [S of forma]; Oborne, Dorset. Figured *M.*, 1892 pl. LVI, fig.i, p. 310; see also *Quart. Journ. Geol. Soc.*, vol. xlix, 1893, p. 501. [6715].

Dorsetensia subtecta S. Buckman 1892, forma S. Buckman 1892 [H of forma]; Frogden Quarry, Oborne, Dorset. Figured *M.*, 1892, pl. LIV, fig. 3, p. 309; see also *Quart. Journ. Geol. Soc.*, vol. xlix, 1893, p. 501. [6717].

Dorsetensia tecta S. Buckman 1892 [S]; Oborne, Dorset. Figured *M.*, 1892, pl. LVI, fig. 5; p. 311; see also *Quart. Journ. Geol. Soc.*, vol. xlix, 1893, p. 501 [6716].

Dumortieria grammoceroides Haug, Buckman 1892. See *Fontannesia luculenta.*

Fontannesia luculenta S. Buckman 1902 [H]; Bradford Abbas, Dorset. Figured *M.*, 1892, pl. XLVI, figs. 4, 5, p. 262, as *Dumortieria grammoceroides* Haug. Referred to in *S.*, 1905, p. clxxxix and there designated as type. [6724].

F. luculenta S. Buckman 1902; Bradford Abbas. Figured *M.*, 1892, pl. XLVII, figs. 10-12, p. 262 as *D. grammoceroides* Haug; Referred to in *S.*, 1905, p. clxxxix. [6724].

Grammoceras nannodes S. Buckman 1890; see *Asthenoceras.*

Graphoceras? inclusum S. Buckman 1904 [P. fide S. S. B.]; Frogden Quarry, Oborne, Dorset. Referred to in *S.*, 1904, p. xcviii. [27625].

Graphoceras mirabile S. Buckman 1904 [P. fide S. S. B.]; Dundry, Somerset. Referred to in *S.*, 1904, p. xcvii. [27626].

Graphoceras undulatum S. Buckman 1902 [P.* fide S. S. B.]; Bradford Abbas, Dorset. Referred to in *S.*, 1904, p.xcvii. [12558].

Hyperlioceras deflexum S. Buckman 1904 [P. fide S. S. B.]; Bradford Abbas, Dorset. Referred to in *S.*, 1904, p. cxxii. [12571].

Hyperlioceras discitiforme S. Buckman 1902 [P.* fide S. S. B.]; Burton Bradstock, Dorset. Referred to in *S.*, 1904, p. cxxiv. [12575].

Ludwigella arcuata S. Buckman 1904 [P. fide S. S. B.]; Stoke Knap, near Beaminster, Dorset. Referred to in *S.*, 1904, p. lxxxix; see also *Quart. Journ. Geol. Soc.*, vol. lxvi, 1910, p. 77. [12524].

Ludwigella blanda S. Buckman 1904 [Cast of figured H]; Stoke Knap, near Beaminster, Dorset. Figured *S.*, 1904, pl. XIX, figs. 22, 24, p. lxxxvii. [27611].

Ludwigella casta S. Buckman 1904 [Cast of figured H]; Stoke Knap, near Beaminster, Dorset. Figured *S.*, 1904, pl.XX, figs. 31, 33, p. lxxxix. [27615].

L. casta S. Buckman 1904 [P. fide S. S. B.] Stoke Knap, near Beaminster, Dorset. Referred to in *S.*, 1904, p. lxxxix; see also *Quart. Journ. Geol. Soc.*, vol. lxvi, 1910, p. 77. [12522].

Ludwigella flexilis S. Buckman 1904 [Cast of figured H]; Stoke Knap, near Beaminster, Dorset. Figured *S.*, 1904, pl. XIX, figs. 28, 30, p.lxxxviii; see also *Quart. Journ. Geol. Soc., loc. cit. supra.* [27612].

Ludwigella impolita S. Buckman 1904 [P. fide S. S. B.]; Bradford Abbas, Dorset. Referred to in *S.*, 1904, p. lxxxv. [12521].

Ludwigella micra S. Buckman 1904 [Cast of figured H]; Louse Hill, near Halfway House, Sherborne, Dorset. Figured *S.*, 1904, pl. XIX, figs. 7, 9, p. lxxxix. [27616].

L. micra S. Buckman 1904 [P. fide S. S. B.]; Bradford Abbas, Dorset. Referred to *S.*, 1904, p. lxxxix. [12519].

Ludwigella opaca S. Buckman 1904 [P. fide S. S. B.]; Burton Bradstock, Dorset. Referred to in *S.*, 1904, pp. xc-xci. [12528].

Ludwigella vibrata S. Buckman 1904 [P. fide S. S. B.]; Bradford Abbas, Dorset. Referred to in *S.*, 1904, p. lxxxviii. [12525].

Ludwigia gradata S. Buckman 1904 [P. fide S. S. B.]; Haselbury, Somerset. Referred to in *S.*, 1904, p.lxxi. [12562].

Oecotraustes spiniger S. Buckman 1910 [P. fide S. S. B.]; Dundry, Somerset. Referred to in *Quart. Journ. Geol. Soc.*, vol. lxvi, 1910, pp. 95-96. [24731].

Oedania parvicostata S. Buckman 1904 [Cast of figured H]; Dundry, Somerset. Figured *S.*, 1905, pl. XXI, figs. 7, 9; see also 1904, p. cviii. [27628].

Pleydellia comata S. Buckman 1904 [Cast of figured H]; Burton Bradstock, Dorset. Figured *S.*, 1904, pl. X, fig. 11. [27606].

Pseudographoceras literatum S. Buckman 1904 [P. fide S. S. B.]; Chideock Quarry Hill, near Bridport, Dorset. Referred to in *S.*, 1904, p. xci; see also *Quart. Journ. Geol. Soc.*, vol. lxvi, 1910, p. 63. [12552].

Reynesia coela S. Buckman 1902 [P.* fide S. S. B.]; Frith Quarry, near Stroud, Glos. Referred to in *S.*, 1904, p. civ. [12543].

Sonninia camura S. Buckman 1894 [S]; Bradford Abbas, Dorset. Figured *M.*, 1894, pl. XCIX, fig. 6, pp. 386, 403. [12594].

Sonninia crassibullata S. Buckman 1893 [S]; Bradford Abbas, Dorset. Figured *M.*, 1893, pl. LXXX, fig. 3, p. 353; see also 1894, p. 400. [12597].

Sonninia gibbera S. Buckman 1893 [Paratypes]; Bradford Abbas, Dorset. Figured *M.*, 1893, pl. LXXXVIII, fig. 1, [12588]; figs. 2, 3. [12589]; see also 1894, p. 421.

Sonninia locuples S. Buckman 1893; Bradford Abbas, Dorset. Figured *M.*, 1893, pl. XCII, fig. 4; 1894, pp. 391, 431. [12598].

Sonninia parvicostata S. Buckman 1892 [S]; Bradford Abbas, Dorset. Figured *M.*, 1892, pl. LXXV, fig. 5, p. 339; see also 1894, p. 396. [12592].

Sonninia spinosa S. Buckman 1893; Bradford Abbas, Dorset. Figured *M.*, 1894, pl. CIII, fig. 23, p. 394; see also 1893, p. 365. [12601].

Sonninia subdecorata S. Buckman 1893 [S]; Bradford Abbas, Dorset. Figured *M.*, 1893, pl. LXXXIV, fig. 11, p. 361; see also 1894, p. 413. [12590].

Sonninia substriata S. Buckman 1892 [S]; Bradford Abbas, Dorset. Figured *M.*, 1892, pl. LXXI, fig. 8, p. 330. [12599].

S. substriata S. Buckman 1892; Stoke Knap, near Beaminster, Dorset. Figured *M.*, 1894, pl. CIII, fig. 12; p. 406. [12591].

Sonninia sp.; Bradford Abbas, Dorset. Figured *M.*, 1892, pl. LXX, fig. 4 as *S. simplex* S. Buckman; see also 1894, p. 439. [12593].

Sonninia sp.; Bradford Abbas, Dorset. Figured *M.*, 1894, pl. XCVII, fig. 5; p. 440. [12600].

Stokeia subacuta S. Buckman 1904 [P. fide S. S. B.]; Dundry, Somerset. Referred to in *S.*, 1904, p. cxxviii. [12587].

Toxolioceras incisum S. Buckman 1904 [P. fide S. S. B.]; Burton Bradstock, Dorset. Referred to in *S.*, 1904, p. cxxvi; see also *Quart. Journ. Geol. Soc.*, vol. lxvi, 1910, p. 74. [12559].

B. *Upper Lias Ammonites*

Catulloceras aratum (S. Buckman 1891) [H]; Penn Wood, near Stroud, Glos. Figured *M.*, 1891, pl. XXXIX, figs. 3-5 as *Dumortieria arata* S. Buckman; described as *Catulloceras*, *M.*, 1892, p. 280. [6720].

Catulloceras dumortieri (Thiollière MS., Dumortier 1874); Burton Bradstock, Dorset. Figured *M.*, 1891, pl. XXXIX, figs. 6-9; described *M.*, 1892, pp. 277-8; see also *Quart. Journ. Geol. Soc.*, vol. lxvi, 1910, p. 69. [6718].

Catulloceras insignisimile (Brauns 1867); Stinchcombe Hill, Dursley, Glos. Figured *M.*, 1891, pl. XXXIX, figs. 12-14; described *M.*, 1892, p. 278. [6722].

Catulloceras leesbergi (Branco 1879); Wooton-under-Edge, Glos. Figured *M.*, 1891, pl. XXXIX, figs. 10, 11; described *M.*, 1892, p. 279. [6721].

Catulloceras subaratum Brasil 1895; Trent?, Somerset. Figured *M.*, 1891, pl. XXXIX, figs. 1, 2, 2a, as *Dumortieria arata* S. Buckman var. and described *M.*, 1892, p. 280 as *Catulloceras aratum;* and in *S.*, 1905, p. clxxii as Brasil's species. [6719].

Dumortieria arata S. Buckman 1891, see *Catulloceras aratum* and C. *subaratum*.

Dumortieria arenaria S. Buckman 1905 [Cast of figured H]; Bradford Abbas, Dorset. Figured *S.*, 1905, pl. XXII, figs. 34, 36; p. clxxxv. [27603].

Dumortieria linearis S. Buckman 1905 [P. fide S. S. B.]; Chideock Quarry Hill, near Bridport, Dorset. Referred to in *S.*, 1905, p. clxxxiii; see also *Quart. Journ. Geol. Soc.*, vol. lxvi, 1910, p. 64. [27604].

Dumortieria pseudoradiosa (Branco 1879); Yeovil Junction, Dorset. Figured *M.*, 1891, pl. XLI, figs. 1-3; p. 246. [6727].

Haugia grandis S. Buckman 1898 [Cast of P]; Coaley Wood, Dursley, Glos. Figured *M.*, 1889, pl. XXIII, fig. 14, and described *M.*, 1890, p. 146, as *Haugia variabilis* (d' Orbigny 1844); see also *S.*, 1898, p. xxvi. [27597].

Haugia variabilis (d'Orbigny) see *H. grandis*.

Polymorphites senescens S. Buckman 1892 [H]; Haresfield Hill, Glos. Figured *M.*, 1892, pl. XLVIII, figs. 13-15; p. 268. [6725].

C. *Lower Lias Ammonites*

Schlotheimia charmassei? (d'Orbigny); Redcar, Yorks. Figured S. Buckman, 'Some Lias Ammonites: *Schlotheimia* and Species of other Genera,' *Proc. Cotteswold Nat. F.C.*, vol. xv, 1906, pl. X, figs. 19, 20, p. 239. [14034].

IX.—THE GROUP OF LARGE CARBONICOLAS WHICH CHARACTERIZE THE BASE OF THE MIDDLE COAL MEASURES

BY

W. B. WRIGHT, Sc.D.

Text-figure 1.

THE Mussel-band above the Arley Mine of Lancashire has long been a well-known index horizon in that coalfield. The exceptionally large species of *Carbonicola* which abounds in this bed was identified by Wheelton Hind with *C. robusta*[1] and was until 1929 referred to by this name. At that date the writer called Professor Trueman's attention to the fact that this shell bore a very slight resemblance to Sowerby's species, the type of which was moreover so imperfect that it was difficult to ascertain what was really intended by the name *C. robusta*. The same difficulty having been experienced by Professor Trueman in naming shells from Nottinghamshire it was agreed that a new name for Hind's form was desirable and a specimen figured by Hind and preserved in the Manchester Museum was described in that year by Professor Trueman under the name *C. pseudorobusta*. The type specimen is from the Lower Yard Seam of Fulledge Colliery, Burnley, in the northern part of the Lancashire Coalfield.

The ascertained position of the well-known mussel-band containing this species is some 120 to 160 ft. above the Arley Mine which forms the base of the Middle Coal Measures in Lancashire, but it is clear that there are other beds that yield similar large species. All are, however, confined to the lower portions of the Middle Coal Measures and form in the middle of the Ovalis Zone a convenient and well marked subzone, the characteristic species of which, *C. pseudorobusta,* is much commoner than *C. ovalis* and consequently more generally useful in stratigraphy.

It is found, however, that the fauna of these beds is variable and includes in some localities forms which can hardly be described as *C. pseudorobusta* but resemble very closely the series of shells figured by Wheelton Hind from the Cockshead Coal, Adderley Green, North Staffordshire and named by him *C. acuta*. Referring to these shells Hind says:—

> "In many specimens there exists a feature denied to this species [*C. acuta*] by M'Coy, namely a subconstriction or oblique sulcus, widening as it approaches the ventral border, and showing a close relationship to similar forms of *C. robusta* [*C. pseudorobusta,* Trueman], with the

[1] The authors of the species referred to in this paper are indicated in the following list:—*Carbonicola robusta* (J. de C. Sowerby), *C. pseudorobusta*, Trueman, *C. ovalis* (Martin), *C. acuta* (J. Sowerby), *C. communis* Davies and Trueman, *C. rhomboidalis* Hind, *C. phrygiana* Wright, *C. aquilina* (J. de C. Sowerby), *C. os-lancis* Wright, *C. pectorata* Wright, *C. subconstricta* (J. Sowerby), *C. binneyi* Wright, *C. fallax* Wright, *Anthracomya minima* Auctt., *Jonesina arcuata* (Bean), *C. centralis* Hind, *C. angulata* Hind.

smaller elongated form of which shell, indeed, *C acuta* is closely allied, differing chiefly in the relatively smaller dorsoventral and lateral measurements."[1]

It is clear, therefore, that Hind recognised the affinity of these forms to *C. pseudorobusta*, and, as Davies and Trueman[2] in 1927 so restricted *C. acuta*, that they could no longer be referred to the latter species, they have been left without a name, unless, as suggested by Clift and Trueman[3] in 1929, they may be referable to *C. communis* Davies and Trueman. In referring to a similar fauna from Nottinghamshire, Clift and Trueman say :—

> " The species of *Carbonicola* which occur over the Low Main Seam may probably be regarded as forming a homogeneous community, and they include forms that may be named, *C. communis* Davies and Trueman, *C. robusta* Hind (*non* Sowerby) [=*C. pseudorobusta* Trueman] and *C. rhomboidalis* Hind. The assemblage may be compared with that above the Cockshead Seam of North Staffordshire and the Lower Vein of Ystalyfera (Glam.) ; but in these cases the specimens do not attain so great a size, while the height of the shell is generally smaller in proportion to the length, as has been shown to be the case also in the smaller specimens associated with the Low Main Seam."

The above quotation clearly suggests that in the opinion of the writers the name *C. communis* is applicable to certain of the specimens figured by Wheelton Hind from the Cockshead Seam, and this may be true of one or two of them in which the posterior truncation is more rounded off than in the normal type, but the name cannot be applied to the most characteristic form found in the bed. The need of a name for the latter having been badly felt in the Lancashire Coalfield it seems desirable to raise it to the status of a species, selecting as type one of Hind's specimens.

Carbonicola crista-galli sp. nov.

Text-figure 1.

1894. Carbonicola acuta (J. Sowerby) Hind *pars*, ' Monograph on Carbonicola Anthracomya and Naiadites ', *Palaeont. Soc.*, pl. iii, figs. 4-12.

Holotype.—No. 46672. Natural History Museum, South Kensington figured by Wheelton Hind : *op. cit.*, plate iii, fig. 8, 1894. Also in Naturalist 1906, plate xxii, fig. 2.

Locality.—Roof of the Cockshead Coal, Adderley Green, North Staffordshire.

Description.—Shell somewhat elongate, moderately tumid and with moderately prominent umbones, the anterior lobe always a little less than one third of the length. Maximum depth beneath

[1] Hind, Wheelton, ' Monograph on Carbonicola, Anthracomya and Naiadites.' *Palaeont. Soc.*, 1894-1896 p. 53.

[2] Davies, J. H., and A. E. Trueman, ' A Revision of the Non-Marine Lamellibranchs of the Coal Measures ' : *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927, p. 210.

[3] Clift, S. G., and A. E. Trueman, ' The Sequence of Non-Marine Lamellibranchs in the Coal Measures of Nottinghamshire and Derbyshire ' : *ibid.*, vol. lxxxv, 1929, p. 83,

the umbones, and generally between 50 and 60 per cent. of the length. Viewed in lateral outline the slightly curved or straight posterior umbonal slope is truncated obliquely by the posterior margin, which makes with it an angle of about 140°, and the slightly curved posterior margin makes a rounded angle of 60 or 70° with the lower margin. The latter is almost straight as far forward as the point beneath the umbones, where it sweeps up into the well-rounded anterior margin. The anterior lobe of the shell is fairly high and the anterior umbonal slope of moderate length and only slightly re-entrant. The maximum thickness is a little behind the umbones and the shell tapers gradually to the posterior end. The lines of growth are parallel to the lower margin.

Dimensions of holotype.—l = 49 m/m. h = 55%. t = 37%. a = 26.5%.

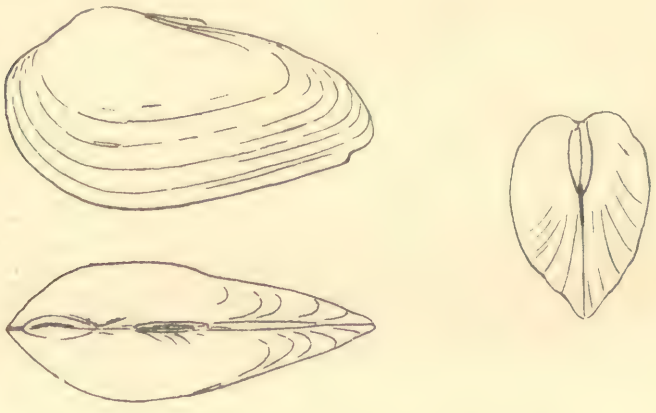

FIG. 1—Carbonicola crista-galli *sp. nov. Holotype. B.M. no.* 46672. *From the roof of the Cockshead Coal Seam, Adderley Green, North Staffordshire.*

Notes.—As pointed out by Wheelton Hind a few specimens show an oblique sulcus descending to the inferior margin, which is thus slightly incurved. In this respect they show an approach to *C. pseudorobusta,* but lack the sub-umbonal depth and tumidity of that species.

With still greater development of the inflexion of the lower margin the shell becomes indistinguishable from *C. os-lancis,* var. *pectorata,* which thus has relationships with forms lower in the succession than *C. os-lancis.* In these circumstances it seems desirable to erect this supposed variety into an independent species, *Carbonicola pectorata*[1].

About half the shells from the Cockshead Seam are referable to Hind's variety *rhomboidalis,* which has been raised to specific rank

[1] For description and figure see W. B. Wright, 'The Zonal Succession in the Coal Measures round Manchester': 'Summary of Progress for 1928,' Part II, (*Mem. Geol. Surv.*) 1929, p. 40 and plate ii, fig. 7.

by Davies and Trueman. This form differs from *C. crista-galli* in having a markedly curved posterior umbonal slope and the maximum depth of the shell well behind the umbones, or at least extending well back from the latter. The growth lines are commonly tilted or make an angle with the lower margin. The relation of *C. rhomboidalis* to *C. crista-galli* is similar to that of *C. phrygiana* to *C. aquilina*[1].

This is a much more robust form than either *C. subconstricta* of the subzone below or *C. os-lancis* of that above and it has a straighter lower margin than the latter. The posterior truncation is also less sharply marked. *C. communis* is distinguished from it by having a rounded posterior end. As it is doubtful if those varieties which show some approach to *C. pseudorobusta* can be distinguished from *C. pectorata* of the Trencherbone, it is quite likely that there is no hard or fast line between the species known as *C. pseudorobusta, C. crista-galli, C. rhomboidalis, C. communis, C. subconstricta, C. pectorata* and *C. os-lancis.*

The Pseudorobusta Fauna is well developed on three horizons as follows :

C, The Roof of the Yard Mine.
B, 60 ft. above the Smith or Rushy Park Mine.
A, 100-140 ft. above the Arley Mine.

Horizon A is the well-known index bed of the South-east Lancashire Coalfield. It is well exposed at Eagley, north of Bolton where it yielded *C. pseudorobusta, C. binneyi,* and *A. minima,* the specimens of *C. binneyi* being in the upper part of the band. In the Wigan area the bed has been seen in nine localities with variations in the recorded fauna as follows :—

1. Parsonage Colliery, West Leigh : *C. pseudorobusta, Naiadites, Jonesina arcuata* and, 5 ft. higher, *C. binneyi.*
2. Arley Hall Stream-section : *C. pseudorobusta, C. crista-galli.*
3. Ellerbeck Colliery, Coppull : *C. pseudorobusta, C. crista-galli, C. communis, C. pectorata, A. minima, Naiadites, Spirorbis.*
4. Langtree Colliery, Standish : *C. communis, C. subconstricta, C.* cf. *centralis, C.* cf. *angulata.*
5. Victoria Pit, Standish : *C. pseudorobusta, C. crista-galli, C. rhomboidalis, A. minima.*
6. Welch Whittle Colliery, Wrightington : *C. crista-galli, C. rhomboidalis, C. binneyi, C.* cf. *subconstricta, Naiadites, Spirorbis.*
7. Orrell Brick Pit : *C. crista-galli, C. rhomboidalis.*
8. Holland Colliery, Upholland : *C.* cf. *communis, C.* cf. *subconstricta.*
9. Ravenhead Colliery, St. Helens : *C.* cf. *subconstricta, C.* cf. *communis* and round forms.

Of the above localities (4), (8) and (9) lack the large form characteristic of the fauna elsewhere. The horizon is approximately the same but they may possibly not be the same bed. The only generalization that can be made regarding the rest is that *C. pseudorobusta* seems to be replaced westwards by *C. crista-galli,* and it is certainly not the dominant form of the wider horizon in the

[1] Wright, W. B., *op.* cit., 1929, p. 44.

Wigan district. It is worth noting that *C. binneyi,* which at Eagley lay directly on top of the bed with *C. pseudorobusta,* occurred at Parsonage in a separate bed, 5 ft. higher, a circumstance which may account for the failure to find this species in all localities.

Horizon B, about 50 or 60 ft. above the Smith or Rushy Park Mine, is, in the St. Helens district, the most commonly recorded mussel-band. It is accessible unfortunately in only one locality, namely Ravenhead Colliery, St. Helens, and that under circumstances in which its identification might conceivably be erroneous, the bed having been approached across faults. A mistake of this kind is, however, unlikely. The fauna includes *C. pseudorobusta, C. crista-galli, C. rhomboidalis, C. pectorata, Naiadites, J. arcuata, Spirorbis* and Fish.[1]

Horizon C, above the Haigh Yard has only been seen in two localities both lying in the west of the field. At Birkacre Colliery, Coppull, this bed yielded *C. pseudorobusta, C. rhomboidalis, C. communis, C. crista-galli, A. minima, J. Arcuata* and Fish. The other locality, in the River Yarrow, near Chorley, was too difficult to collect. In other places, as for example at Langtree Colliery, Standish, the Yard Mine has a plant-bearing roof apparently without *Carbonicola.*

A curious feature of the Pseudorobusta Subzone is the intercalation right in the middle, in the roof of the Smith or Rushy Park Mine, of a bed containing no trace of the large forms dealt with above, but yielding only the Lower Coal Measure form *Carbonicola fallax.* The roof of the Bone Coal immediately above the Rushy Park is generally barren but in one locality, Crawford Colliery, Aspull Moor, it yielded a number of Carbonicolas of fair size referable to *C. crista-galli, C. communis, C. rhomboidalis* and *C.* cf. *subconstricta.*

The Cannel Mine might be cited as a stil higher horizon of this fauna, which however is only known above this seam in one locality, namely Langtree Colliery, Standish, where it occurs in association with *Anthracomya minima, Naiadites* and Ostracods, elsewhere the only forms found in this bed. *C. crista-galli, C. rhomboidalis* and *C.* aff. *pseudorobusta* are represented. Indeed, *C. rhomboidalis* and *C. crista-galli* range still higher into the base of the Modiolaris Zone. As seems commonly to be the case in the *Carbonicola* faunas of the Coal Measures, the variability of the groups introduces a state of affairs in which extreme forms are more characteristic of certain horizons than the generalized forms into which they pass by small variations. The generalized forms have a much longer range in time and probably also a much wider distribution. Thus *C. crista-galli, C. rhomboidalis* and *C. communis* have undoubtedly a longer range than *C. pseudorobusta.*

[1] Since going to press the Arley index bed has been located in a boring in St. Helens in its normal position some 100 or 120 ft. above the Arley Mine. It is much reduced in prominence, being only about 3 in. in thickness. It may therefore be assumed that the much stronger bed in Ravenhead Colliery is correctly located as above the Rushy Park Mine.

The latter is therefore a better zonal form, but, as we have seen, it is liable to be replaced laterally by *C. crista-galli*.

On the whole it seems likely that the varied development of the Pseudorobusta Fauna is largely a matter of nourishment and of conditions of growth, the weaker smaller forms being merely those individuals which from environment or chance failed to reach full development. The shells above the Rushy Park are, however, probably a different stock.

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